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December 1995

US Army Corps
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Waterways Experiment
Station

Road Management Plan and Workshop, Eglin Air Force Base, Florida

by Paul E. Albertson, Albert J. Bush III, Steve L. Webster, John P. Titre, WES
David M. Patrick, James W. Brown, University of Southern Mississippi

Prepared for Natural Resources Branch, Eglin Air Force Base, FL

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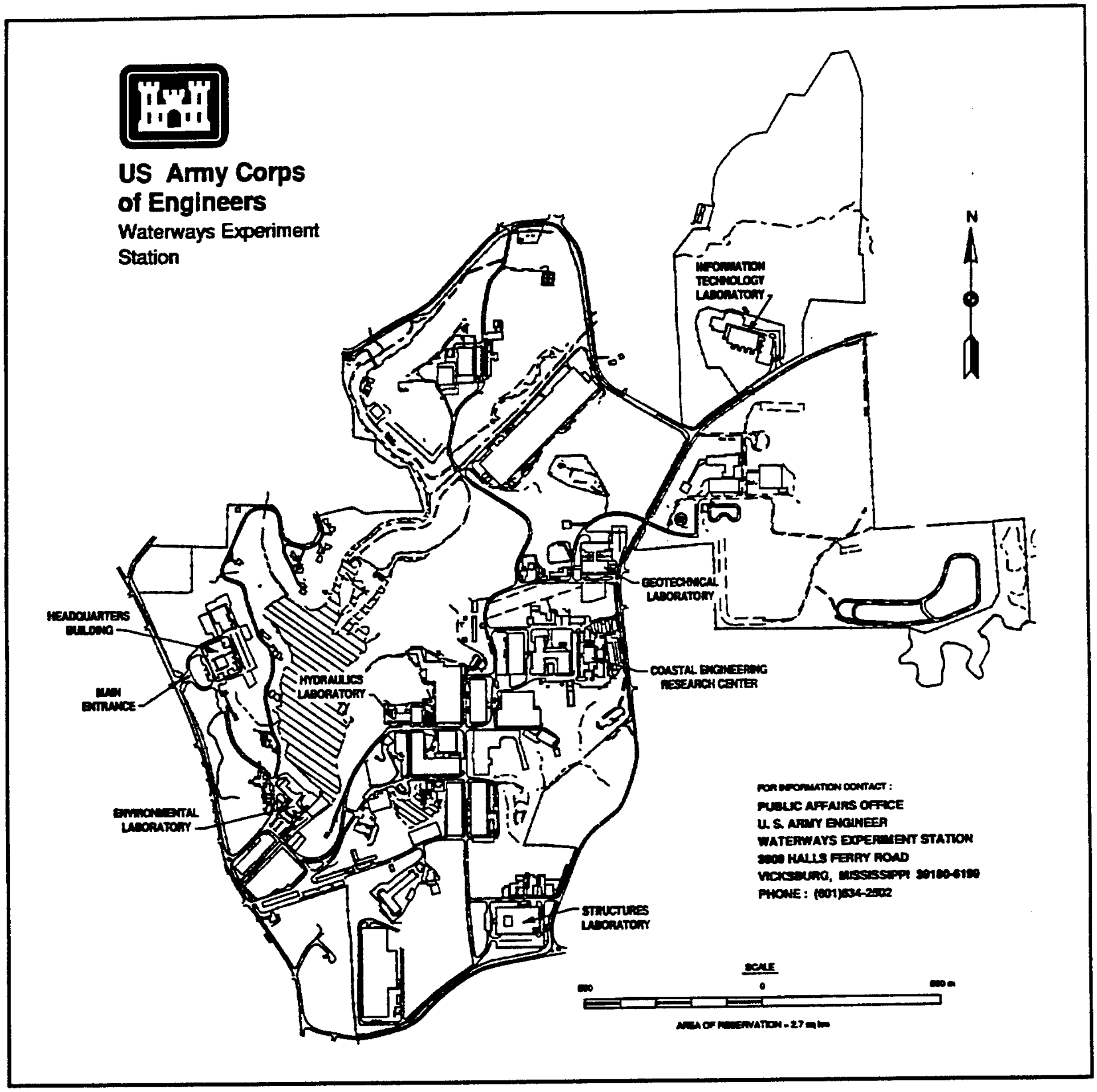
U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

David M. Patrick, James W. Brown

Department of Geology
University of Southern Mississippi
Hattiesburg, MS 39406-5044

Final report

Prepared for Natural Resources Branch
Eglin Air Force Base, FL



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Preface

The work described in this report was conducted by U.S. Army Engineer Waterways Experiment Station (WES) during the period July 1994 through January 1995 and authorized by Eglin Air Force Base, Natural Resources Division (NRD). Mr. Richard McWhite was Chief, NRD, and Mr. Steve Sieber was the Eglin AFB point of contact. The work and report preparation were conducted by Mr. Paul E. Albertson (principal investigator), Engineering Geology Branch (EGB), Earthquake Engineering and Geosciences Division (EEGD), Geotechnical Laboratory (GL); Dr. Albert J. Bush III and Mr. Steve L. Webster, Technology Applications Branch (TAB), Airfields and Pavements Division (APD), GL; Mr. John P. Titre, Resource Analysis Branch (RAB), Natural Resources Division (NRD), Environmental Laboratory, (EL); and Dr. David M. Patrick and Mr. James W. Brown, Department of Geology, University of Southern Mississippi. Technical review of this report was provided by Mr. H. Roger Hamilton, Chief, RAB, NRD, EL; Mr. Donald M. Ladd, TAB, APD, GL; and Dr. Lillian D. Wakeley, Acting Chief, EGB, EEGD, GL.

The authors acknowledge Messrs. Carl Petrick, Ken Bristol, Mike Camizzi, Doug Smith, and many other individuals of NRD for their assistance and for supporting the field work associated with this work. Special thanks to Ms. Marie Stuller, contractor for organizing materials and coordinating the workshop.

This investigation was performed under the direct supervision at WES of Mr. Robert Larson, Chief, Geologic Environments Analysis Section, EGB, EEGD, Dr. A. Gus Franklin, Chief, EEGD, and Dr. William F. Marcuson III, Director, GL.

At the time of publication of this report, Dr. Robert W. Whalin was the Director of WES. Commander was COL Bruce K. Howard, EN.

Executive Summary

In this report a decision-making framework is developed to address the closure of nonmission-essential roads at Eglin Air Force Base (AFB). This framework focuses on whether roads should be developed, maintained, or closed based on mission and ecological constraints. A workshop was conducted at Eglin AFB with those responsible for road management to discuss the future of roads on the base. Technical experts were also involved in conducting preliminary investigations aimed at applying road evaluation practices to conditions at Eglin AFB. While these efforts are intended to produce a road management plan, the actual document will likely involve a series of meetings and actions resulting in on-the-ground changes to roads on the base. Consequently, this report provides a basis for developing such a road management plan to serve as a means for daily decisions about road maintenance and closure.

The benefits of developing a road management plan will be realized in terms of reducing ecological impacts and costs associated with developing and maintaining unnecessary roads. A spiderweb network (approximately 1,500 miles) of roads has evolved at Eglin AFB taxing functional elements beyond their capability to safely care for them. A systematic assessment and inventory of roads needing maintenance or closure is required. The fragmented authority for road management called for a workshop to devise strategies that would end inefficient attention to roads while complying with statutory environmental requirements.

During early discussions with staff members from the Natural Resources Management Division, it became evident that the problem of where to find reliable borrow pit material to surface sandy erodible roads would only serve as a partial solution. The U.S. Army Engineer Waterways Experiment Station (WES) was asked to help address the larger issue of road management since they had experience with on-site investigations related to borrow pit materials. WES could also provide additional technical assistance in applying criteria to the job of inventorying and evaluating roads based on procedures and computer programs already developed. Field exercises were conducted as part of a workshop to acquaint participants with evaluation techniques and criteria. Expert testimony was provided regarding existing Army/Air Force and U.S. Forest Service road standards and their application to soil conditions at Eglin AFB.

Following the field exercises and the actual workshop, two principal recommendations were forwarded. First, a **Task Force should be formed with representatives from major functional elements responsible for road management and chaired by the Natural Resources Management Division.** This Task Force could meet regularly to make adjustments to the road management plan. Individual efforts to address roads would be replaced by consensus-driven actions that are environmentally sound and economically efficient. A second recommendation was to **adopt road management criteria developed at the workshop.** Procedures are available and provided in this document to inventory and evaluate roads. Some modifications will be necessary to adjust techniques for application at Eglin AFB. Suggestions were provided to organizationally carry out actions to implement these recommendations. This involves agreement on a Road Inventory and Prioritization Plan to begin evaluating sectors on a pilot study basis.

Finally, a useful decision-making framework was provided to visually orient the Task Force toward actions in developing a Road Management Plan. This can be used in Task Force meetings to chart progress with respect to individual actions. Much of the work to achieve such a plan can be accomplished by the staff at Eglin AFB. Aspects of criteria development and technical assistance will enhance the plan especially during the early stages. The challenge is to begin now by using this document to convene a Task Force meeting and discuss the results. There is an opportunity not only to address problems at Eglin AFB but to serve as a model for other military installations.

1 Introduction

Purpose and Scope

The purpose of this report is to describe the results of preliminary investigations of strategies, decision criteria and framework for the closure of nonmission-essential roads at Eglin Air Force Base, Florida. Figure 1 shows the location of Eglin AFB. The objectives of these studies were to:

a. Contribute to the determination of what roads should be developed, maintained, and/or closed.

b. Provide information relative to the development of construction and maintenance standards for unpaved roads.

c. Provide input into a road management plan.

d. Develop consensus and identify user needs through a workshop and field exercise held at Eglin during the period 15-16 September 1994.

The strategies, consensus, and criteria presented herein are considered applicable to the entire installation; however, they are presented in terms of a pilot study conducted in the Duke Field area shown in Figure 2.

Problem Statement

Eglin occupies approximately 464,000 acres in portions of Okaloosa, Walton, and Santa Rosa Counties, Florida and has an extensive network of almost 1,500 miles of roads. Most of these roads are unpaved, are located in remote field areas, and their construction and location have evolved through past and current mission requirements and recreational activities. This road network has resulted in two interrelated issues. The first pertains to costs of maintaining such an extensive system and who should pay for the maintenance, and the second pertains to environmental degradation resulting from the existence of the unpaved road system and the maintenance of the system. Most of this report addresses the second issue. Most of Eglin is

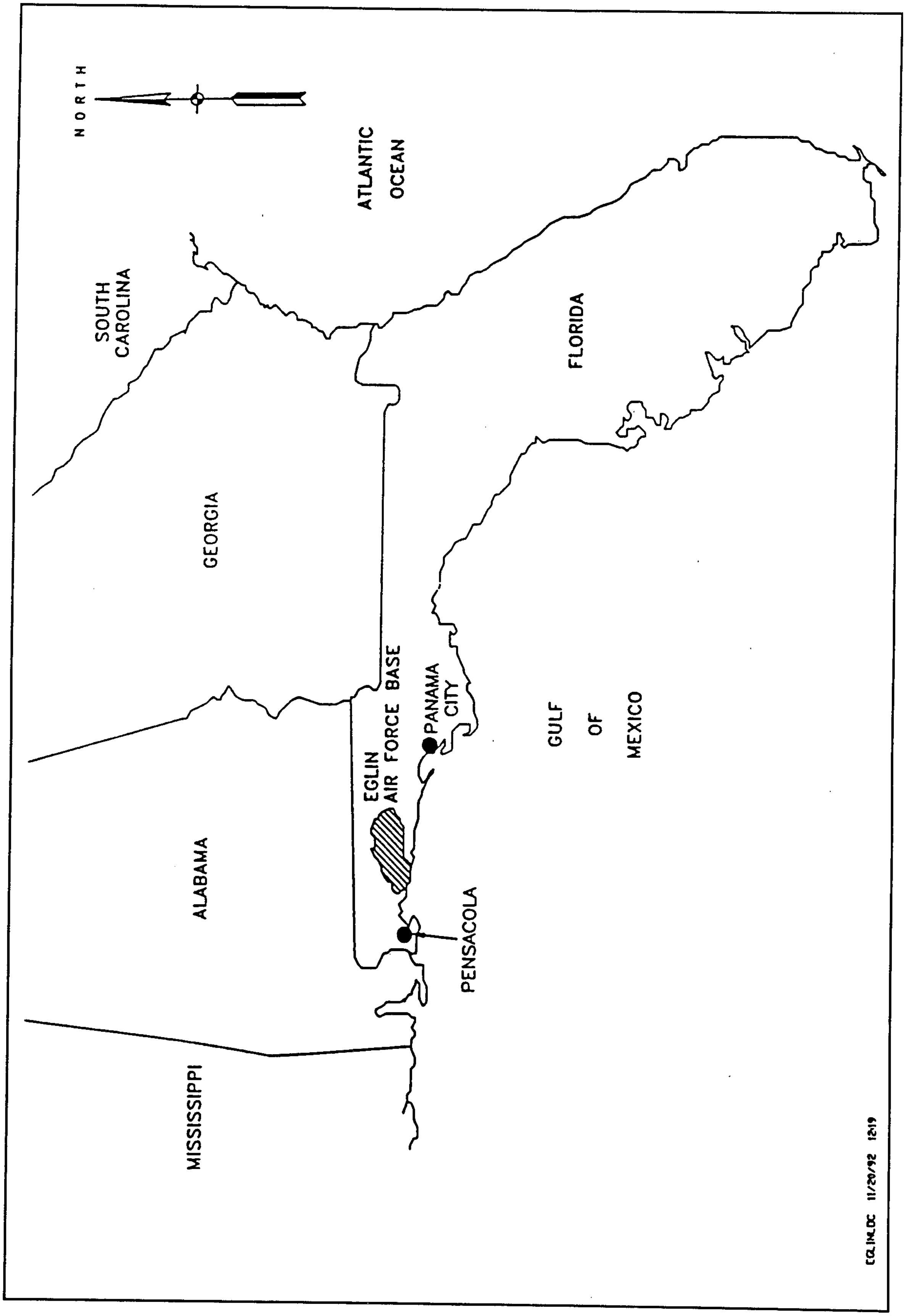


Figure 1. Location map of Eglin Air Force Base

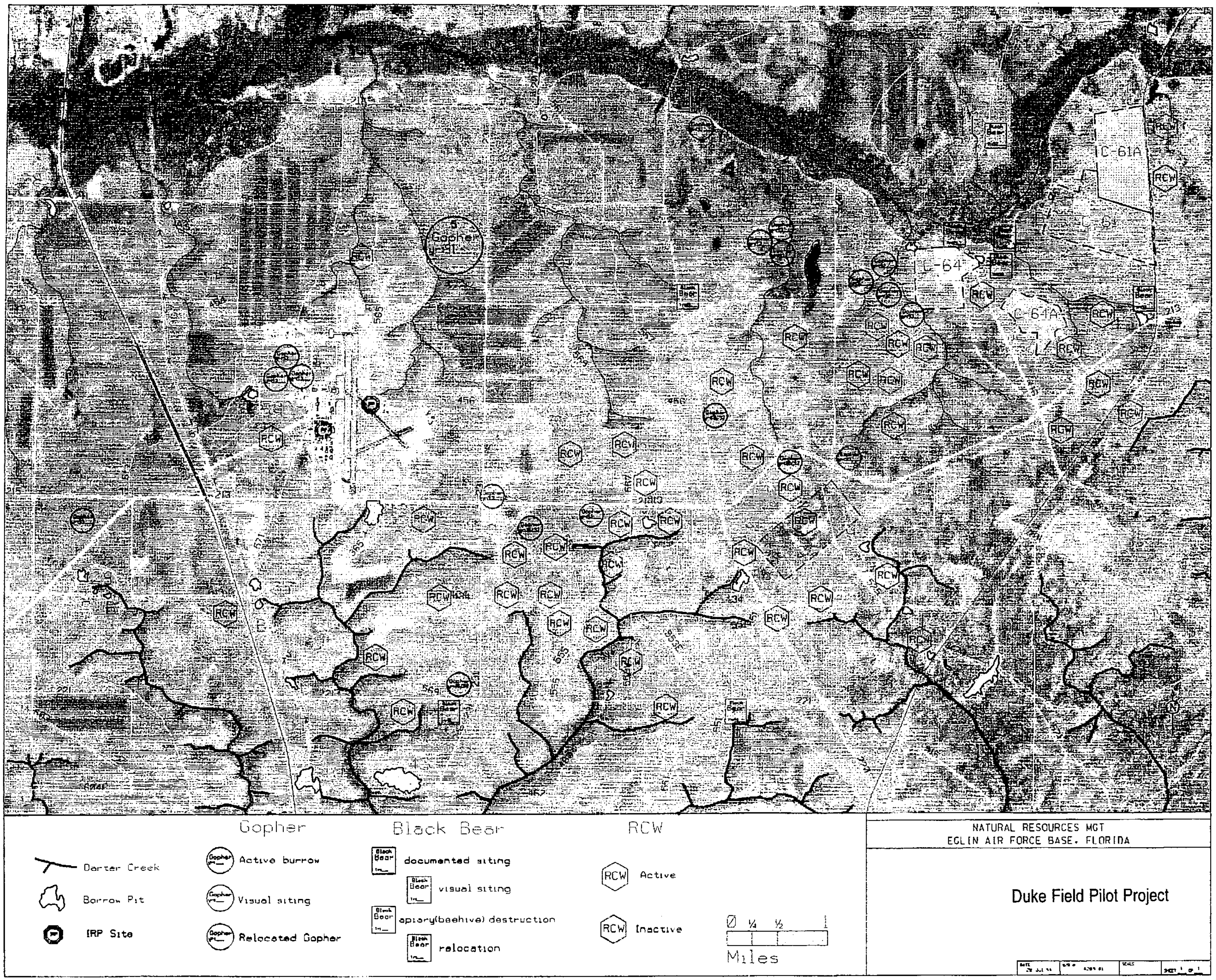


Figure 2. GIS map layer showing the Duke Field Pilot Study area and critical features

covered by sandy material which is quite erodible; thus, the unpaved road system has become line and point sources of erosion. Sediments are eroded from and along the roads and transported to nearby streams. Sedimentation has the potential of adversely impacting wetlands and riparian fish habitats including those of the protected Okaloosa darter (*Ethostoma okaloosae*). Road maintenance is a derivative environmental issue because of the nearly 165 borrow pits which have been opened on the installation to provide materials for the surfacing of these roads. Many of these borrow pits are located near roads and streams and they have become point sources of erosion and they are contributing sediments to the stream system on the installation. Thus, the unpaved road system has resulted in potentially adverse impacts which are regulated by the following legislation:

a. Clean Water Act.

b. EO 11990 Protection of Wetlands (1977).

c. Endangered Species Act of 1973.

In addition to the environmental costs, the expense of keeping the roads up to mission standards needs greater consideration. Lacking is an inventory of the existing road network with consideration toward closing nonmission-essential roads. Actions taken toward conducting an inventory and subsequent evaluation will likely reduce costs while minimizing environmental impacts.

Background

The Eglin AFB Natural Resources Management Plan identified road management as an issue and a management concern. The following quote is taken from the management plan regarding roads:

> "What road systems should be closed/developed and what road standards should be set on the Eglin reservation? The existing road network on Eglin is extensive, many secondary roads and trails serve no useful purpose. An extensive program is planned to close unnecessary roads, correct erosion problems, and restore the forest to a more natural state. The primary issue is coordination with military and official government users of the road system to determine real requirements, and impacts to some recreation user groups, such as dog hunters (USAF, p. III-4, 1993)."

In terms of borrow or clay pits, the management plan offers the following:

> "Controls were not placed to regulate the number and location of clay pits. Anywhere clay could be found close the surface became a potential site due to the ease in removing the sand overburden. This has resulted in extreme erosion from most

> pits due to their location on slopes adjacent to streams. --- Erosion from existing pits is degrading wetlands and riparian areas including the habitat of the Okaloosa darter (USAF, p. VI-16, 1993)."

Concerned with the road impacts on natural resources, Natural Resources "Jackson Guard" staff consulted with Mr. William R. Webb of the U.S. Forest Service (USFS). The following excerpts from his site visit report offer additional insight into the problem.

> "These roads reflect several common characteristics: The roads are old, well established travel ways that have been abraded and eroded, thru time, to the point that the centerline grade is much lower than the surrounding ground on either side. This depressed condition is resulting in excessive concentrations of surface water running down the road and ditch lines which results in water quality degradation at stream crossings."

Mr. Webb's full assessment is included in Appendix A. The benefit of Mr. Webb's wisdom was unfortunately lost due to staff reduction in the USFS and his retirement. Therefore, Eglin's Natural Resource Division looked for other experts to assist with the road management concerns.

The Legacy Earth Resources Task Area team at WES conducted studies on clay borrow material used for surfacing and maintaining unpaved roads at Eglin. As an outgrowth of the Legacy Earth Resources inventories at Eglin AFB, the Natural Resources Division requested that WES assist in developing road management criteria. In response to the request, a WES team was formed to conduct the work.

Approach

Road management investigations were conducted through the following tasks:

a. Task 1. Literature review considering existing Department of Defense (DOD) road specifications, other DOD road management plans, U.S. Forest Service standards, and relative data from Eglin.

b. Task 2. Conduct a workshop during which input could be received from road users and managers.

c. Task 3. Develop criteria for road closure on the basis of consensus of workshop participants, related research and accepted standards for road development, maintenance, and closure.

2 Environmental Setting and Constraints

The Situation

Unpaved roads, borrow pit occurrence, and the nature of the local earth materials comprise interrelated issues which, either separately or combined, pose potentially adverse environmental consequences. For example, approximately 165 borrow pits have been opened on Eglin in order to meet construction and maintenance requirements, particularly surfacing the nearly 1,500 miles of roads on the installation. Of these 165 pits, approximately 31 are active, many have been abandoned, some have been closed, others are programmed for closure, and selected pits are intended to be expanded. The abandoned and operational pits as well as the roads pose environmental challenges because of concerns that sediment produced by erosion of these pits and roads may adversely affect water quality and, in turn, the flora and fauna, in nearby streams. Furthermore, borrow pit closure, road surfacing, and environmental mitigation also pose economic challenges.

Earth Materials

Much of Eglin is underlain by non-cohesive sandy sediments which were deposited by fluvial, eolian, and near-shore marine processes during Tertiary and Quaternary times. The occurrence of clay or clayey materials at or near the surface is highly limited. The materials occurring at the surface are relatively clean sands classified by the USDA as the Lakeland Series. The Lakeland soils are immature and are formed upon clean sands (SP, SP-SM), which were probably deposited upon a terrace surface during the Quaternary. The thickness of the sands is variable; however, it may range from zero or a few feet to several ten's of feet. The principal engineering properties of the Lakeland soils are described in Table 1. Generally, the Lakeland is brown in color and does not possess sufficient fines [silt (ML) and clay (CL)] and cohesion suitable for road surfacing. Surface soils which do possess fines and, hence, more cohesion are the Tifton and Troup Series soils whose properties are also shown in Table 1. The Troup soil is categorized as a Grossarenic Paleudult, and the Tifton, generally, as a Plinthic Paleudult. Both soils are red to reddish brown in color and their area of occurrence is

extremely limited. The materials used for road surfacing occur in the shallow subsurface generally underlying the Lakeland soils and they are similar to the Troup and, in particular, the Tifton Series.

Table 1
Classification and Physical Characteristics of the Lakeland, Tifton, and Troup Soil Series (from USDA SCS Soil Survey Data)

Soil	Depth (ft)	USCS[1] Class[2]	Clay (%)	PI	Permeability (in./hr)
Lakeland	0-40	SP-SM	1-8	NP	6-20
	40-80	SP, SP-SM	1-6	NP	6-20
Tifton	0-16	SM	10-20	NP-7	6-20
	16-34	SM	13-22	5-20	6-20
	34-60	SM	20-35	11-21	0.6-2
	60-80	SC, CL	25-40	11-21	0.2-0.6
Troup	0-60	SM, SP-SM	5-6	NP	6-20
	60-80	SM-SC, CL-ML	15-19	4-10	0.6-2

[1] USCS = Unified Soil Classification System.
[2] SP = Sand poorly graded; SP-SM = Sand with 5-12% fines;
SM = Silty sand >12% fines; ML = Silt; CL-ML = Clayey silt; CL = Silty clay.

Nature and Origin of the Borrow Materials

Most of the desired, cohesive, construction materials excavated from the borrow pits and used for road surfacing underlie the Lakeland soil and its parent materials by a few feet to a few ten's of feet. The thickness of the cohesive material is approximately four or five feet, and is a red (or reddish-brown), silty or clayey sand. This sand is underlain by brown sands containing less fines. The thickness of the brown sands is usually a few feet and these sands are, in turn, underlain by relatively clean, tan to white sands. Generally, the materials targeted for excavation are the red or reddish-brown sands; however, some of the less cohesive over and underlying materials may also be removed. Usually, the red sands appear case-hardened in the sides of the pits and red-brown mottling is present in these sands and in those underlying them. The red sands are similar in texture and mineralogy to the Troup and Tifton in terms of clay and silt content and in terms of the presence of kaolinite, gibbsite, and a 14-angstrom clay mineral. The Tifton soil is lateritic and the texture, mineralogy, and appearance (such as case hardening)

of the red sands are also similar to lateritic soils. The case hardening is probably due to cementation by the aluminum (gibbsite) and iron (hematite or goethite) minerals in the sand. The hematite or goethite also imparts the red color to the sands.

The tentative conclusion is that the construction materials underlying the Lakeland soil and its parent material is a paleosol which is similar to the Troup and Tifton. Thus, prior to the deposition of the Lakeland soil parent material, weathering and pedogenic processes produced the red sand upon an earlier geomorphic surface or surfaces. This view is supported by the fact that the occurrence of the red sands is not controlled by elevation; that is, the red sands are found to occur at elevations ranging from 25 to 175 ft above mean sea level. This means that the origin of the red sands is not directly related to depositional or sedimentological processes and that these materials cannot be traced great distances laterally across the installation. Also, the red sands are associated with all but the lowest geomorphic surface or terrace which have been identified at Eglin.

Borrow Material Texture and Classification

Approximately 140 borrow pit sites were visited including those in open and closed areas. Sixty-seven of those visited were measured, described, and sampled. Grain-size analyses were run on samples from 57 pits. X-ray diffraction analyses were performed on samples from eight pits. Table 2 shows the average percent clay indicated by (C) and silt indicated by (M) across the installation by U.S. Geological Survey (USGS) quadrangle. All of the samples tested would be classified as silty or clayey sands (SM or SC). Atterberg limits were not determined; however, on the basis of the amount of clay and the types of clay minerals present, these materials would probably have low cohesion and they would be classified as SM (silty sand) in the Unified Soil Classification System. The engineering properties of materials classified as SM would not be ideal for most applications such as road surfacing due to low clay content and absence of gravel.

Table 2
Average Percent Clay and Silt of Borrow Materials by USGS Topographic Quadrangle

WEST			NORTH			EAST
		8.2%(C) 7.7%(M) (2) Holt	14.7% (C) 10.2% (M) (2) Crestview South	6.7% (C) 7.7% (M) (6) Spencer Flats	8.7% (C) 7.7% (M) (6) Mossy Head	8.4% (C) 5.6% (M) (1) De Fun Sp
10.0% (C) 10.9% (M) (3) Ward Basin	7.3% (C) 8.0% (M) (6) Harold SE	6.1% (C) 3.4% (M) (4) Holt SW	9.9% (C) 4.9% (M) (11) Valparaiso	10.9% (C) 4.7% (M) (5) Niceville	8.7% (C) 4.0% (M) (5) Niceville SE	14.7% (C) 8.6% (M) (4) Portland
	7.7% (C) 6.4% (M) (4) Navarre					
			SOUTH			

3 Road Management and Closure

Overview

The management and closure of unpaved roads at Eglin must be based upon a number of factors or considerations developed by the Corps of Engineers and Forest Service which include:

a. The road network is a system and, as such, must be evaluated using an integrated systems-oriented and synoptical approach.

b. The road network on the reservation must support the traffic, load, and vehicle requirements of a variety of mission and recreational requirements, some of which may be conflicting.

c. Decisions on closure must, to a certain extent, be based upon a consensus among those responsible for road management.

d. Consideration must be given to flexibility with respect to unforeseen future training and mission requirements.

e. Plans should address the concept of temporary roads which, after being used for a mission, may be closed.

f. Design, construction, and maintenance standards must be determined or adopted.

g. Road management plans must enhance environmental protection and stewardship of natural and cultural resources.

h. These plans should be based upon generally acceptable technical criteria as these relate to the natural setting.

i. Maintenance of unpaved roads should be a part of the installation operating budget.

j. The management plan must be explained to users and to the public alike in order to obtain support.

k. Safety requirements must be a part of the plan.

Road Closure Procedures

The successful management of road networks and closure of nonmission essential road components must consist of eight procedures or steps which encompass all necessary mission and user-related, technical, and database aspects of the system. These steps are outlined below.

Road identification

All roads, trails, and passes must be identified, classified, and located on maps or imagery. At Eglin, many of the smaller, less used roads and trails are not marked on USGS topographic maps and must be located (identified) from imagery. The roads and trails should be included in GIS databases and they should be identified in terms of their function, e.g. individual paved or unpaved roads, tank or equipment trails, range roads, parking areas, etc. For example, the road classification system used by the U.S. Forest Service is shown in Table 3 below can be used to classify roads. There are four levels of service.

Table 3
Road Classification

Level	Function	Standard	Flow	Paved	Surface	Open	Closed
A Paved Primary	Arterial	High	2 to 4 lanes	Yes	Blacktop	X	
B Unpaved Primary	Collector	Medium	2 lanes	Only in sensitive stretches	Gravel or clayey sand	X	
C Unpaved Secondary	Connector	Low	1 to 2 lanes	No	Clayey sand	X	X
D Unpaved Tertiary	Local	Low to None	1 lane	No	None		X

X = Level C roads maybe open only for administrative purposes or seasonally. Level D roads are closed after special mission need. Closure involves, posting with sign, blocking with barracks and re-vegetating with grass or native species.

Mission and traffic category

Identified roads should first be classed as one of the following: Primary, Training, Security, Fire, Recreation, or Other. Then, they should each be rated as: 1 (Required), 2 (Support), or 3 (Not Required). Roads having multiple missions should be rated with the lowest number rating. The traffic category is determined on the number of vehicles per day which travel the road. The traffic categories are: I (200 or more), II (100-199), III (50-99), IV (25-49), and V (0-25).

Road rating system

Having established the locations, mission, and traffic category of all roads and trails, sampling units should be determined for the various road categories and sections. Two sampling units per mile of road are needed; they should each be 100 ft long, they should include the whole width of road, and they should be representative of the road section. The rating system should identify signs of distress such as: improper cross-sections, inadequate roadside drainage, corrugations on surface, dust, potholes, ruts, and loose aggregate. The method recommended to rate road is the Unpaved Road Classification Index (URCI).

Unsurfaced road rating system

The unsurfaced road condition survey and rating procedures should be conducted as described in "Unsurfaced Road Maintenance Management" (Eaton and Beaucham 1992). All roads and trails in Eglin's unsurfaced road network should be located and identified. The unsurfaced road network should be divided into components which include branches, sections, and sample units. A branch is an identifiable part of the unsurfaced road network that is a single entity and has a distinct function. For example, individual roads, parking areas, trails, and range roads are separate branches of the road network. The branches should be identified using Eglin's existing name identification system. The branches are divided into sections that have consistent characteristics throughout their length, such as structural composition, construction history, traffic, and surface condition. In order to inspect and rate the roads each section is divided into sample units. Two sample units per mile of road are needed; they should include the whole width of the road and should be representative of the road section. The sample units should be chosen to insure that the survey measurements will give a fair estimate for the entire section.

Once the unsurfaced road network is divided into branches, sections, and sample units, field survey data can be obtained and the Unsurfaced Road Condition Index (URCI) of each section determined. The field condition survey identifies severity levels for the following road distress types; improper cross section, inadequate road side drainage, corrugations, dust, potholes, ruts, and loose aggregate. The URCI is then calculated to rate the integrity

and surface operational condition of each unsurfaced road section on a scale from zero (failed) through 100 (excellent) as illustrated in Figure 3. An example of a completed inspection sheet used for rating a sample unit is shown in Figure 4.

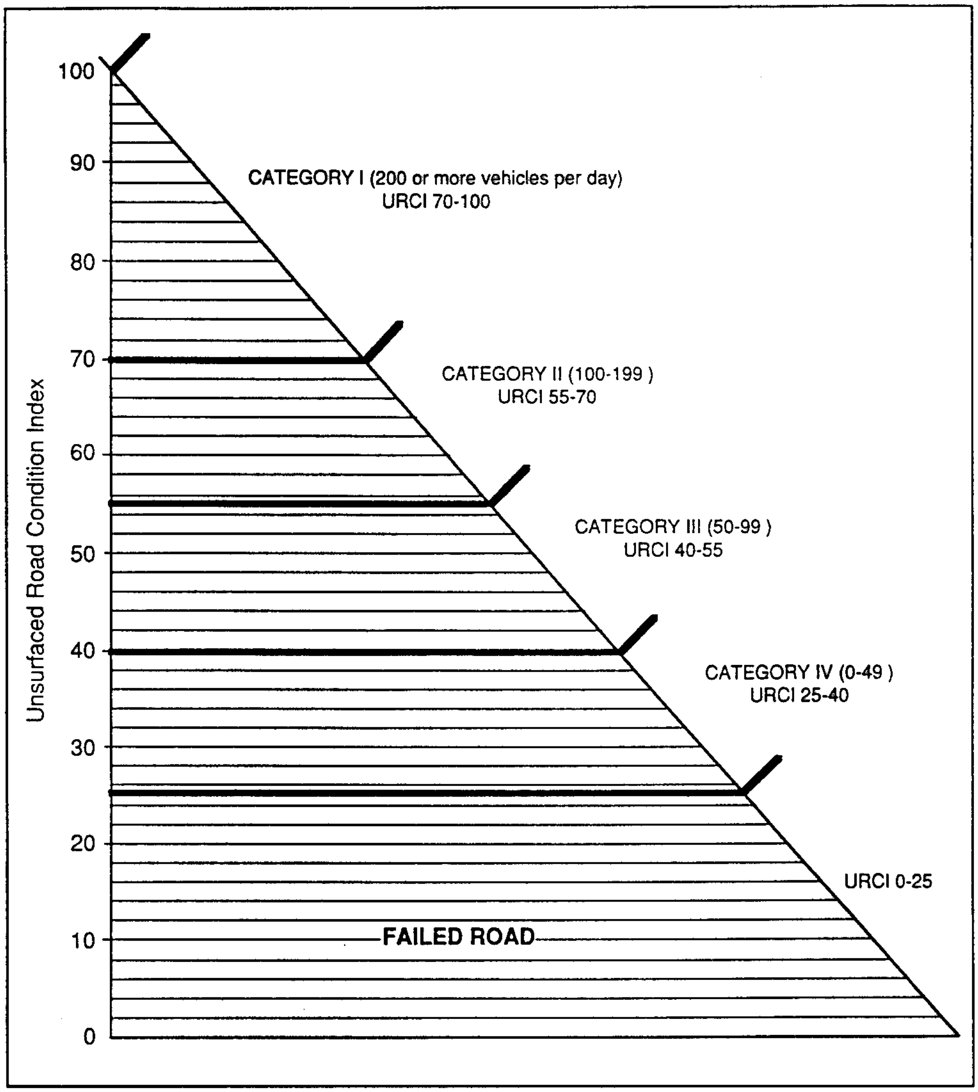


Figure 3. Maintenance priority graph

Sediment erosion category

A three-tiered subjective classification system may be used for this evaluation. For example: High, indicating large amounts of sediment on roads crossing streams or on steep slopes; Medium, relative flat roads parallel to streams; and Low, no evidence or indication of erosion.

UNSURFACED ROAD INSPECTION SHEET

Branch ______________________ Date 16 SEPT 94

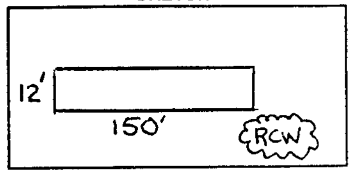
Section ______________________ Inspector A. BUSH / S. WEBSTER

Sample Unit ______________________ Area of Sample 1800 SQ FT

DISTRESS TYPES

81. Improper Cross Section (linear feet)
82. Inadequate Roadside Drainage (linear feet)
83. Corrugations (square feet)
84. Dust
85. Potholes (number)
86. Ruts (square feet)
87. Loose Aggregate (linear feet)

SKETCH



DISTRESS QUANTITY AND SEVERITY

Type		81	82	83	84	85	86	87
Quantity and Severity	L			40			600	300
	M	150						
	H		300					

URCI CALCULATION

Distress Type	Density	Severity	Deduct Value
81	8	M	22
82	17	H	38
83	2	L	2
86	33	L	24
87	17	L	18

Total Deduct Value = 104

q = 4

URCI = RATING = 37

REMARKS:

Figure 4. Unsurfaced road inspection sheet

Road closure criteria

The criteria upon which road closure may be quantified and closure ranking established is shown in Table 4 in which the priority of road closure would be 1. The closure rating of 1 consists of a road with low (3) Mission need, poor road condition with a URCI of 0-10, High erodibility (H) and low traffic volume (V).

Table 4
Road Closure Ranking (1 = High, 4 = Low)

Road Closure Rankings				
Rankings	1	2	3	4
Mission need	3	3	3	3
Traffic	V	V	V	V
URCI	0-10	0-10	10-25	10-25
Erodibility	H	M	H	M

Maintenance and closure guidelines

Maintenance standards should be developed or adopted for roads selected to remain open. Maintenance guidelines from Chapter 4 of "Unsurfaced Road Maintenance Management" (Eaton and Beaucham 1992) are included as Appendix B. Additional maintenance terms from the USFS are included in Appendix C. Roads which are scheduled for closure should be barricaded by gates or earthen dams and clearly marked as closed as shown in Appendix D. Erosion and drainage problems should be repaired by grading and, finally, vegetation should be reestablished. In some cases of severe erosion, the base material should be removed.

Data management

The data, criteria, and standards described in the previous seven steps should be entered into and maintained in the installation GIS. Those roads having road closure rankings of 1 through 4 should be identified through the GIS. Evaluation should be done objectively by users and technical personnel. Once evaluated, certain criteria such as mission can be weighed as more important before final decisions are made. Based upon this review, selected road components should be scheduled for closure.

Design and maintenance standards

There are many different criteria to consider in determining accesses. The U.S. Forest Service Design Criteria and Roadway Drainage are included in Appendix E. The Army/Air Force Technical Manual Standards TM 5-822-12 and TM 5-822-2/AFM 88-7, Chap. 5, are included in Appendix F. Additional evaluation is needed to reach agreement on a final set of standards for Eglin AFB. These existing standards are presented as a foundation for that effort.

Based on the Design Hourly Volume (DHV), Eglin's two-lane unsurfaced roads would be classified as Class D and E according to TM 5-822-2/AFM 88-7, Chap. 5. Single lane access roads to unmanned facilities at Air Force installations will be classified as "class F roads" and shall be designed in accordance with the geometric design criteria presented for class F roads. Table 5 is extracted from TM 5-822-2/AFM 88-7, Chap. 5, highlighting the design controls and elements for class D, E and F roads.

Table 5
Design Controls for Unsurfaced Roads on Eglin AFB (after TM 5-822-2/AFM 88-7, Chap. 5)

Design Controls	Class D Two-lane Road Primary	Class E Two-lane Road Secondary	Class F Single-lane Road Tertiary
DHV	Over 150	10-149	Under 10
Design speed, mph	45-55	45-55	20-30
Average running speed	40-50	25-40	20-25
Minimum lane width (ft)	10	10	10
Lateral clearance (ft)	10	10	10
Minimum shoulder width (ft)	8	6	4
Normal cross-section in/ft	1/2 to 3/4	3/4 to 1	3/4 to 1
Type	Stabilized with select material	Compacted soil	Compacted soil

The thickness design of aggregate-surfaced roads is similar to the design of flexible-pavement roads. The procedure involves assigning a class to the road being designed based on the number of vehicles per day. A design index and subgrade CBR strength are determined and used with design curves to determine the surface thickness requirements for the road. The minimum thickness according to TM 5-822/AFM 88-7 is 4 in.

The road surfacing material should meet certain criteria. It should be sufficiently cohesive to resist abrasive action. It should have a liquid limit no greater than 35 and a plasticity index of 4 to 9. It should be graded for maximum density and minimum volume of voids in order to enhance optimum moisture retention while resisting excessive water intrusion which would lead to rutting and erosion. Recommended gradations are shown in Table 6. Lack of good aggregate sources at Eglin AFB limit the available road surfacing materials to silty or clayey sand from on-base pits. The pit materials probably don't meet the recommendations shown in Table 6 and may require stabilization.

Table 6
Gradation for Aggregate Surface Courses

Sieve Designation		No. 1	No. 2	No. 3	No. 4
25 mm	1 in.	100	100	100	100
9.5 mm	3/8 in.	50-85	60-100	---	---
4.7 mm	No. 4	35-65	50-85	55-100	70-100
2.0 mm	No. 10	25-50	40-70	40-100	55-100
0.425 mm	No. 40	15-30	24-45	20-50	30-70
0.0075 mm	No. 200	8-15	8-15	8-15	8-15

Note: The percent by weight finer than 0.02 shall not exceed 3 percent.

Comparison of the TM specifications No 3 and 4 to gradation from pits B-43, A-01, C-51 and C-07 (Tables 7, 8, 9 and 10) reveals that borrow materials DO NOT meet recommended specifications. TM 5-822-12 states that if the fine fraction exceeds the specification limit, then chemical treatment such as lime can be used to reduce the adverse affects of the clays. Guidance is presented in Army TM 5-822-14/AFMAN 32-82-8010, "Soil Stabilization for Pavements." The manual presents criteria applicable to roads having a stabilized surface layer. It addresses stabilization using cement, lime, fly ash, bitumen, or combinations of these materials.

Performance criteria need to be developed to determine which materials available at Eglin AFB performs the best as road surfacing. Additional work needs to be conducted to develop optimum stabilization methods for the surfacing materials for use in critical areas such as slopes near stream crossings. Good surfacing materials reduce maintenance requirements and retard erosion. For example, milled asphalt has been successfully utilized for slope areas. Experience has shown that concrete fords work for shallow streams while concrete box culverts are better for large stream crossings.

The two primary causes of deterioration of aggregate-surfaced roads requiring frequent maintenance are the environment and traffic. Rain or water flow will wash fines from the aggregate surface and reduce cohesion, while traffic action causes displacement of surface materials. In addition to maintenance requirements, compaction and drainage requirements are important considerations that should be addressed in developing design and maintenance standards for Eglin AFB. Geometric design criteria for roads at military installations are presented in Army TM 5-822-2/AFM 88-7, Chap. 5. Geometric design policies for classified roads within "open" areas of military installations and typical road cross sections are included. Since a number of the roads at Eglin AFB were built to U.S. Forest Service Standards, road maintenance and closure standards used by the U.S. Forest Service are included in Appendix C, D, and E. The above information is presented as a foundation for developing design and maintenance standards for unpaved roads

at Eglin AFB. Refer to Chapter 4 in CRREL Special Report 92-26 for maintenance and repair guidelines (Appendix B).

Table 7
Grain-Size Characteristics of Eglin Sediments from Selected Borrow Pits in Terms of Road Specifications - East Side: Pit C-51

Sieve Size (mm)	Specification No.		Soil/Sediment Name and Depth		
	No. 3	No. 4	Lakeland (0-15 ft)	Tifton/Troup (15-21 ft)	Citronelle (21-30 ft)
	Percent Passing by Weight				
2.00	40-100	55-100	100.0	99.65	99.83
0.425	20-50	30-70	81.29[1]	79.74[1]	95.27[1]
0.075	8-15	8-15	8.26	22.60[1]	16.82[1]
0.0625	[2]	[2]	7.19	20.3	11.6
0.020	3 or less	3 or less	4.9[1]	17.1[1]	9.4[1]
0.0020	[2]	[2]	3.52	12.13	7.75

[1] Out of specifications.
[2] Not given.

Table 8
Grain-Size Characteristics of Eglin Sediments from Selected Borrow Pits in Terms of Road Specifications - Duke Field Area: Pit C-07

Sieve Size (mm)	Specification No.		Soil/Sediment Name and Depth	
	No. 3	No. 4	Lakeland (0-14 ft)	Tifton/Troup (14-27 ft)
	Percent Passing by Weight			
2.00	40-100	55-100	100.0	100.0
0.425	20-50	30-70	73.79[1]	65.36
0.075	8-15	8-15	3.16[1]	6.74[1]
0.0625	[2]	[2]	3.08	5.18
0.020	3 or less	3 or less	2.75	3.2[1]
0.0020	[2]	[2]	2.31	3.26

[1] Out of specifications.
[2] Not given.

Table 9
Grain-Size Characteristics of Eglin Sediments from Selected Borrow Pits in Terms of Road Specifications - Central Area: Pit B-43

Sieve Size (mm)	Specification No.		Soil/Sediment Name and Depth			
	No. 3	No. 4	Lakeland (0-14.5 ft)	Tifton/Troup (14.5-25 ft)	Citronelle (25-35 ft)	Citronelle (35-39 ft)
	Percent Passing by Weight					
2.00	40-100	55-100	100.0	99.88	99.61	98.48
0.425	20-50	30-70	54.96	[3]	33.27	40.67
0.075	8-15	8-15	7.49[1]	[3]	17.49[1]	7.18[1]
0.0625	[2]	[2]	[3]	22.4	14.8	3.15
0.020	3 or less	3 or less	[3]	19.3[1]	13.6[1]	2.5
0.002	[2]	[2]	3.09	10.51	11.51	2.49

[1] Out of specifications.
[2] Not given.
[3] Not determined.

Table 10
Grain-Size Characteristics of Eglin Sediments from Selected Borrow Pits in Terms of Road Specifications - Western Area: Pit A-01

Sieve Size (mm)	Specification No.		Soil/Sediment Name and Depth	
	No. 3	No. 4	Lakeland (0-4 ft)	Tifton/Troup (4-10.5 ft)
	Percent Passing by Weight			
2.00	40-100	55-100	99.35	98.85
0.425	20-50	30-70	59.05	52.63
0.075	8-15	8-15	11.11	16.93[1]
0.0625	[2]	[2]	7.8	16.3
0.020	3 or less	3 or less	5.0[1]	9.78[1]
0.0020	[2]	[2]	3.41	5.2

[1] Out of specifications.
[2] Not given.

4 Field Exercises

Field Exercises

The field exercises were conducted in the Duke Field Pilot Study area (Figure 2). This area was selected for the pilot study because it contained a number of unpaved roads which were believed to be nonmission essential. The area also contains Okaloosa darter (*Etheostoma okaloosae*) streams, red-cockaded woodpecker (*Picoides borealis*), black bear (*Ursus americanus*), and gopher tortoise (*Gopherus polyphemus*) habitats; borrow pits, and Installation Restoration Program sites. The objectives of the field exercises were to acquaint and familiarize workshop participants with field conditions in the area and to demonstrate the URCI. Participants were given a pre-trip briefing on the route and field trip stops prior to departure (Figure 5).

Stop 1

Figure 6 is a view looking west along Road 434 near Stop No. 1. This tertiary road is shown descending into the valley of a tributary of Juniper Creek. Lakeland soil is exposed on the surface of the road and in the cuts on either side. This road has apparently not been recently surfaced. The road exhibits minor rutting, probably because it receives minor traffic. The photograph shows that the road at this point serves as a channel funneling water from the relatively flat upland area into the valley and hence into the tributary. In Figure 7, field trip participants are examining the eroded surface of Road 434 at Stop 1 a short distance to the east of Figure 6.

Stop 2

This stop was along Road 221 and it is shown in Figure 8. WES personnel demonstrated the methodology for monitoring road conditions by measuring the frequency and depth of wheel rutting on this unpaved road. Ruts were measured at intervals along the roadway. The two-by-four board laid across the road provides a convenient and simple method of measuring the depth of the wheel ruts.

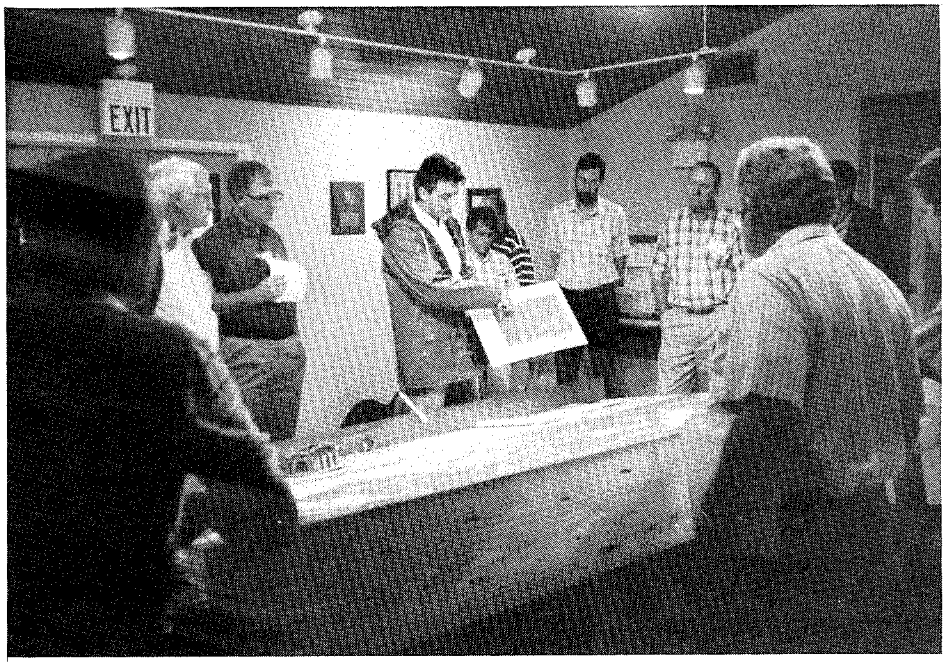


Figure 5. Pre-field trip briefing. Paul Albertson (WES workshop leader) is describing the objectives of the field trip and showing the workshop participants the route through the Duke Field area and the field trip stops

Figure 6. View looking west along Road 434 near Stop No. 1. This tertiary road is shown descending into the valley of a tributary of Juniper Creek. The road at this point serves as a channel funneling water from the relatively flat upland area into the valley and hence into the tributary

Figure 7. Field trip participants are examining the eroded surface of Road 434 at Stop No. 1 a short distance to the east of Figure 8

Stop 3

Stop 3 was along Road 221 at borrow pit C-2. The photograph shown in Figure 9 looking northeast from the road) shows the borrow pit, erosion channels draining the pit, and the failed berm which had been constructed across the pit outlet to the road to prevent runoff. The purpose of this stop was to show the interrelationships between the eroding road, erosion from borrow pit C-2 (located on the north side of the road), and Point Lookout Creek. This creek is a tributary to Juniper Creek and Road 221 crosses the creek a short distance to the west of this stop along Road 221.

Environmental impacts

The interrelations are thus: surface runoff is concentrated in the pit and the concentrated runoff is channeled onto the road; the road itself is a channel for concentrating runoff; and the combined runoff from the pit and the road is delivered down the road and into the creek. Since the materials in the pit and on the road surface are erodible, a significant amount of sediment may accompany the runoff and be delivered to the creek from the road and from the pit. Observation of the bridge deck reveal the presence of sand and one could see a sand bar developed in Point Lookout Creek on the downstream side of the bridge. There is concern that the sediment introduced into the creeks may be adversely affecting stream habitats at Eglin. This concern is particularly directed toward streams which are the endemic habitats of the threatened and endangered Okaloosa darter. Juniper Creek and its tributaries

are not darter habitats; however, the conditions seen at this site are believed to be typical of those along darter streams.

At borrow pit C-2, approximately 20 ft of soils and uncemented sediments are exposed. These materials are somewhat less red or reddish-brown in color and less casehardened that typical borrow materials. The material from the near-surface to 6 ft in depth, 5 percent gravel, 86 percent sand, and 9 percent silt and clay. From 6 to 10 ft, it is 6 percent gravel, 83 percent sand, and 11 percent silt and clay. From 10 to 20 ft, it is 2 percent gravel, 84 percent sand, and 14 percent silt and clay. The relatively small amount of silt and clay, and resulting low cohesion, as well as depth and size of the exposed area in the pit, contribute to the erodibility of these materials and their marginal suitability for road surfacing.

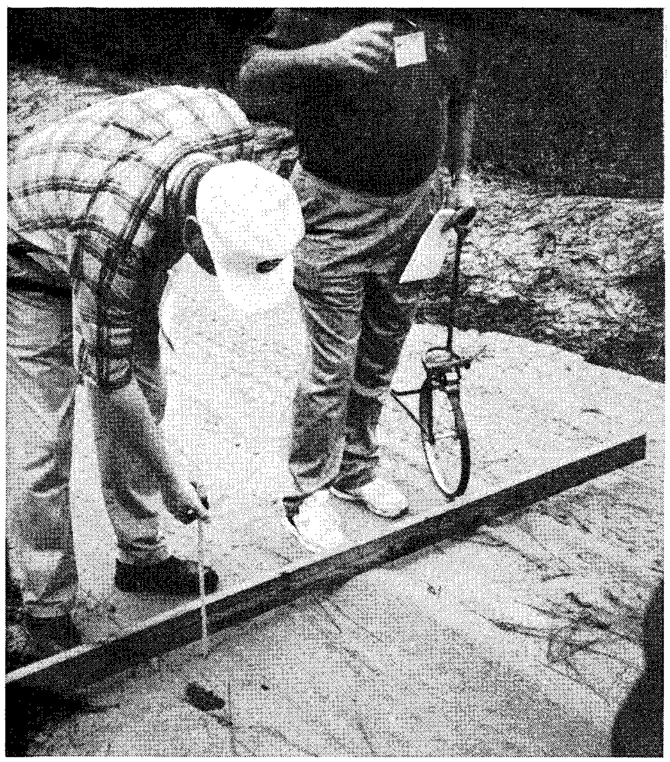


Figure 8. Road 221 at Stop No. 2. WES personnel are demonstrating the methodology for monitoring road conditions by measuring the frequency and depth of wheel rutting on this unpaved road

Figure 9. Shows the borrow pit, erosion channels draining the pit, and the failed berm which had been constructed across the pit outlet to the road to prevent runoff

5 Workshop Exercise

Goals and Objectives

A workshop was held to identify the interests and concerns of those responsible for roads as they relate to mission requirements, ecosystem management and restoration, fire management, recreation, public education, earth resources and forest products. An agenda of the workshop is included in Appendix G. The objectives of the workshop were to:

a. Identify and exchange existing information from road users and technical personnel.

b. Develop general criteria for road management.

c. Develop consensus among users for road management.

Workshop participants represented the functional elements of Eglin AFB. A list of attendees is included in Appendix H. They have a working understanding of the road problem from their respective functional responsibilities. The workshop speakers were individuals with technical background in natural resource management and/or road management. The workshop consisted of short talks on clay borrow material, road design and management to provide subject content for the issues to be discussed. The workshop sessions used a modified nominal group technique (NGT). Results of the workshop are included in this report to help set priorities for the collection, assimilation, and analysis of data for the decision making. Findings can also be used for establishing guidelines for road development, maintenance, and closure.

The workshop established a dialogue for those attending to share different perspectives and first-hand experiences with road management. In a dialogue, positions are not rigidly held and people are willing to listen to others and interact to promote constructive change. Such an atmosphere aided in making this a true workshop rather than a training course (Figures 10 and 11). Based on personal experiences, participants shared information about managing roads from a foundation of talks about proper road management. This combination of technical information and practical application are essential elements toward preparing road management plan for Eglin AFB.

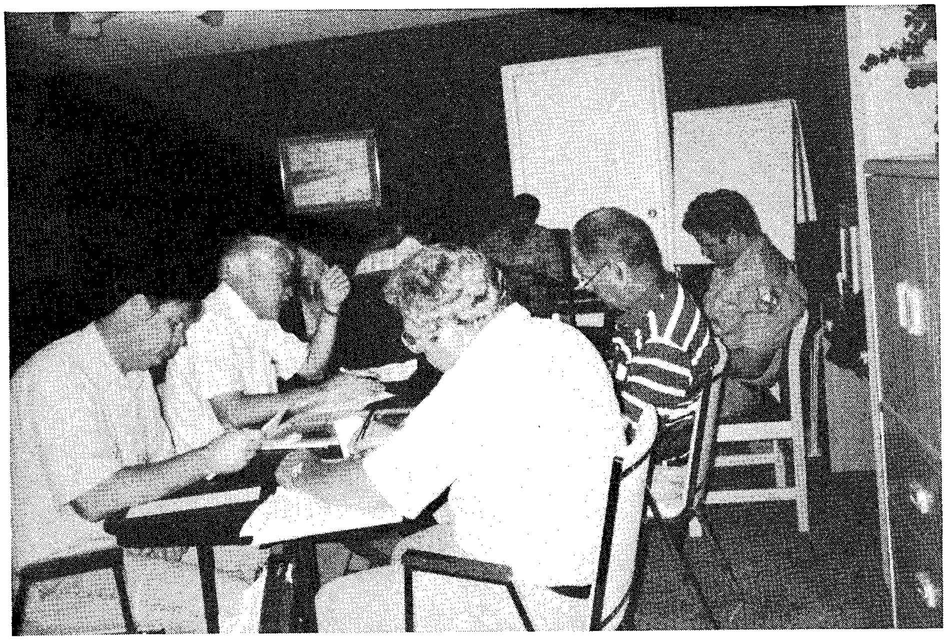


Figure 10. Photograph of workshop participants, working in small groups, developing objectives and possible courses of action for road closure

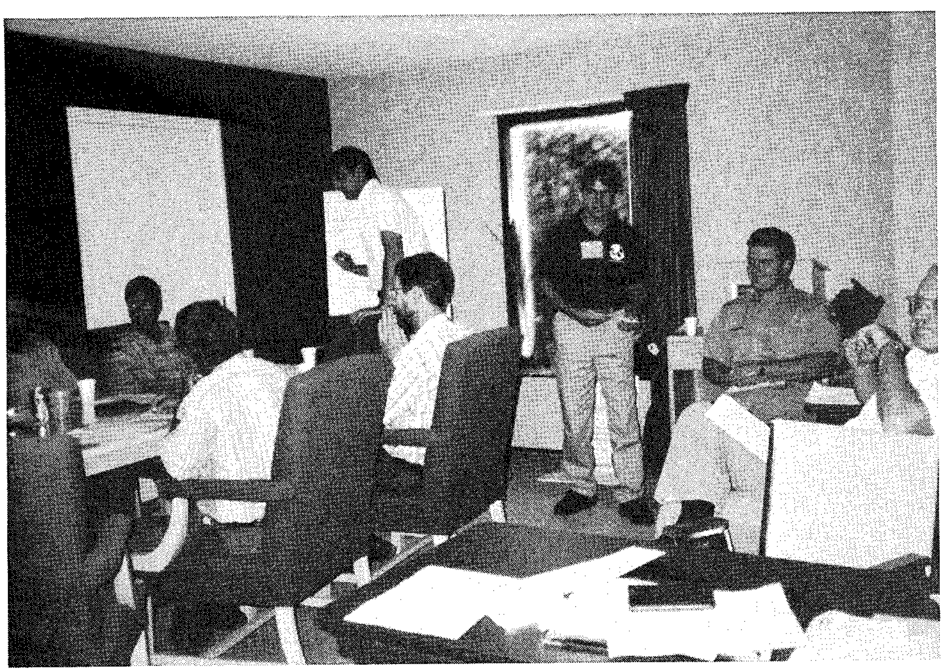


Figure 11. Photograph of workshop participants, having developed group courses of action, interacting with workshop leaders to develop the integrated plan

Workshop Methods

The discussion groups were organized prior to the workshop with a leader appointed to each group. Group assignments were made based on each individual's background and job assignment. The goal was to construct heterogeneous groups to reduce bias in terms of perspectives and functional responsibilities at Eglin AFB. This provided all groups with an opportunity for a balanced response to the problems encountered in addressing the issue of road management.

The goals of NGT are to: (a) promote diversity of viewpoint, (b) promote balanced participation among groups, and (c) develop perception of critical issues. The technique is appropriate for problem identification, solution exploration, and priority setting (Delbecq et al. 1975). The NGT is especially effective when the group is familiar with the problem. This technique was selected since it focuses on setting priorities as participants voice the most important aspects related to road management. The technique is described in detail in Figure 12.

The NGT was modified to limit the time spent in clarification to only those items voted as having high priority. Two questions were used and presented to the groups for discussion: **"How would you improve road management at Eglin Air Force Base?"** and **"Where do we go from here?"** After an explanation of the process, participants were assigned to groups of approximately four to six individuals and these questions were distributed to each group leader. A specified time was announced to finish discussion on the two questions. Workshop organizers were available to clarify questions and other concerns.

As described in Figure 12 (steps 1, 2, and 3), each member of a group responded in writing to the provided question with three ideas they considered to be most important and clarified if necessary. The group leader then wrote all items on poster paper. Ballots were distributed for voting. Sample ballots are provided in Appendix E. Votes were tallied and the five items receiving the most votes were discussed. Only three of the five were forwarded from the group to the plenary session.

In the plenary session, Figure 12 (step 3), the top three items forwarded from each group were listed on poster paper. After the entire group cast individual ballots for the final top five items, these items were discussed.

STEP 1

WRITTEN INDIVIDUAL RESPONSES
(10 MIN MAX)

- O WRITE NOT OVER 3 IDEAS PER QUESTION IN BRIEF PHRASES ON CARDS
- O WORK SILENTLY AND INDEPENDENTLY

STEP 2

INDIVIDUAL FEEDBACK AND GROUP DISCUSSION

- O EACH PERSON PRESENTS HIS OR HER IDEAS
- O MEMBERS DECIDE ON DUPLICATES
- O FACILITATOR RECORDS AND NUMBERS ALL ITEMS
- O EACH PERSON USES BALLOT TO RANK TOP FIVE ITEMS
  - O 5 = TOP RANKING
  - O 1 = BOTTOM RANKING
- O GROUP LEADER USES FINAL TALLY SHEET TO TABULATE RESULTS. RECORDS TOP FIVE.
- O GROUP DISCUSSION ON WHICH 3 TO REPORT TO PLENARY SESSION. CLARIFICATIONS ARE MADE (IF NEEDED).

STEP 3

PLENARY SESSION FEEDBACK

- O ALL CONVENE IN ONE SETTING
- O TOP 3 ITEMS REPORTED FROM EACH GROUP
- O VOTING AND FINAL TALLY
- O DISCUSSION ON TOP 3 ITEMS

Figure 12. Steps 1, 2, and 3 in the modified nominal group technique

Recommendations

A tally of each question is provided in Table 11. The top four responses to the first question formed the basis for recommendations: Prioritize Roads, Classify Roads, Develop Management Plan, and Synthesis of Suggestions (WES). For the second question, "Identify Mission Critical Road Requirements," received nearly twice as many points, 31, as any other item. Other items noteworthy for developing recommendations were: Prioritize Roads for Maintenance, Charter Working Group, and Place Roads on Management Plan. These findings suggest two principal recommendations.

Table 11
Results of the Nominal Group Technique

Items Generated During Breakout Session No. 1	Points
"How Would You Improve Road Management at Eglin Air Force Base?"	
1. Prioritize Roads	18
2. Classify Roads	12
3. Develop Management Plan	11
4. Synthesis of Suggestions (WES)	10
5. Develop Criteria and Standards	8
6. Establish Road Board with Representatives	7
7. Examination and Evaluation of Roads to Test/Range	5
8. Evaluate Environmental Constraints	4
9. Mission/Road Account Project	2
10. Close Secondary and Tertiary Roads	2
11. Evaluate Primary Purpose Roads	1
12. Determine Density Needs	0
Items Generated During Breakout Session No. 2	**Points**
"Where Do We Go From Here?"	
1. Identify Mission Critical Road Requirements	31
2. Prioritize Roads for Maintenance	19
3. Charter Working Group	14
4. Place Roads on Management Plan	11
5. Start Rating System at Range Roads	8
6. List Resources Available for Maintenance	7
7. Eliminate Roads Not Needed	5
8. Identify Road Users	4
9. Perform Maintenance as Needed Using Rating System	2

Recommendation No. 1: Road Management Task Force

Considerable interest emerged in continuing the dialogue created during the workshop toward producing a road plan. It was felt that a plan would allow participants to share their perspectives and knowledge while gaining from others. It is recommended that a Task Force with a chair from the Natural Resource Management Division be formed to facilitate the preparation and implementation of a road management plan. It is important to remember from the workshop exercise that the plan is as much a process as a product. The time and effort spent in exchanging information in preparing the plan will be as valuable as the product to guide road management.

Recommendation No. 2: Adopt Road Management Criteria Presented During the Workshop

General criteria for good roads as presented during the talks provide a basis for developing performance standards to evaluate road management. It is recommended that the Task Force adopt criteria presented during the talks as a foundation for plan preparation. However, these criteria should be pilot tested on a reduced area such as the Field Trip location and later modified for application Base-wide.

The workshop results are only a start in assembling the information necessary for improving the way roads are managed at Eglin AFB. These efforts are a success to the extent that functional elements with Eglin AFB build on this information with internal meetings and written memoranda to refine what was presented and discussed.

Suggested Organizational Steps Toward Producing a Road Management Plan

The following are suggested steps that could be taken toward producing a road management plan.

a. Convene a meeting hosted by the Natural Resource Management Division to discuss the workshop report and findings. (Allow two weeks for report distribution prior to meeting and possibly invite one or more of the WES coordinators to provide input.)

b. Select a pilot study area that needs immediate attention.

c. Adopt criteria found in this report to evaluate roads within the pilot study area.

d. Conduct an analysis of the data and summarize the findings in a brief report for distribution to the Task Force.

e. Present the report at the next quarterly meeting for discussion.

f. Prepare an after-action report evaluating the pilot test results.

g. Develop a Road Inventory Prioritization Plan for a large portion of Eglin AFB.

h. Conduct a meeting of the Task Force to present the Priorization Plan and determine whether a study is needed to further develop and/or refine road criteria.

i. If a study is needed, requisition a roads evaluation criteria study. If a study is not needed, continue evaluating sectors according to the priorization plan and guidelines found in this document.

j. Develop these materials into a Road Management Plan and continue quarterly meetings with after action reports on Task Force progress.

6 Summary and Conclusions

The road system on Eglin AFB was inherited from the U.S. Forest Service and previous mission requirements. A systematic approach to inventory, categorize, and rate the roads has been presented in Chapter 3. Decisions to keep roads open or to close them can be made based on road mission requirements, maintenance condition, and environmental considerations. To draw upon the wisdom of an experienced forester, Mr. Webb (Appendix A), "the logical start point is to inventory the road system." Since the decision making needs to consider multiple users, the inventory procedure should be conducted with the direction of the Task Force.

Synthesizing the workshop recommendations, the future steps are as follows and as shown in the flow chart (Figure 13):

a. Establish a task force which includes but is not limited to experts in mission requirements, civil engineering, natural resources, and roadways such as WES Airfields and Pavements Division.

b. Inventory the road system in terms of:

(1) Mission needs.

(2) Traffic volume.

(3) Maintenance conditions (URCI).

(4) Environmental concerns, such as sediment erodibility.

c. Enter the inventory information in a data base such as micropaver and/or add attributes to the GIS.

d. Make decisions by using the database to query the criteria (Chapter 3) to keep roads open or close them.

e. Open roads fall into two categories, maintenance (Appendix B) or reconstruction (see Appendix E and F for design specifications).

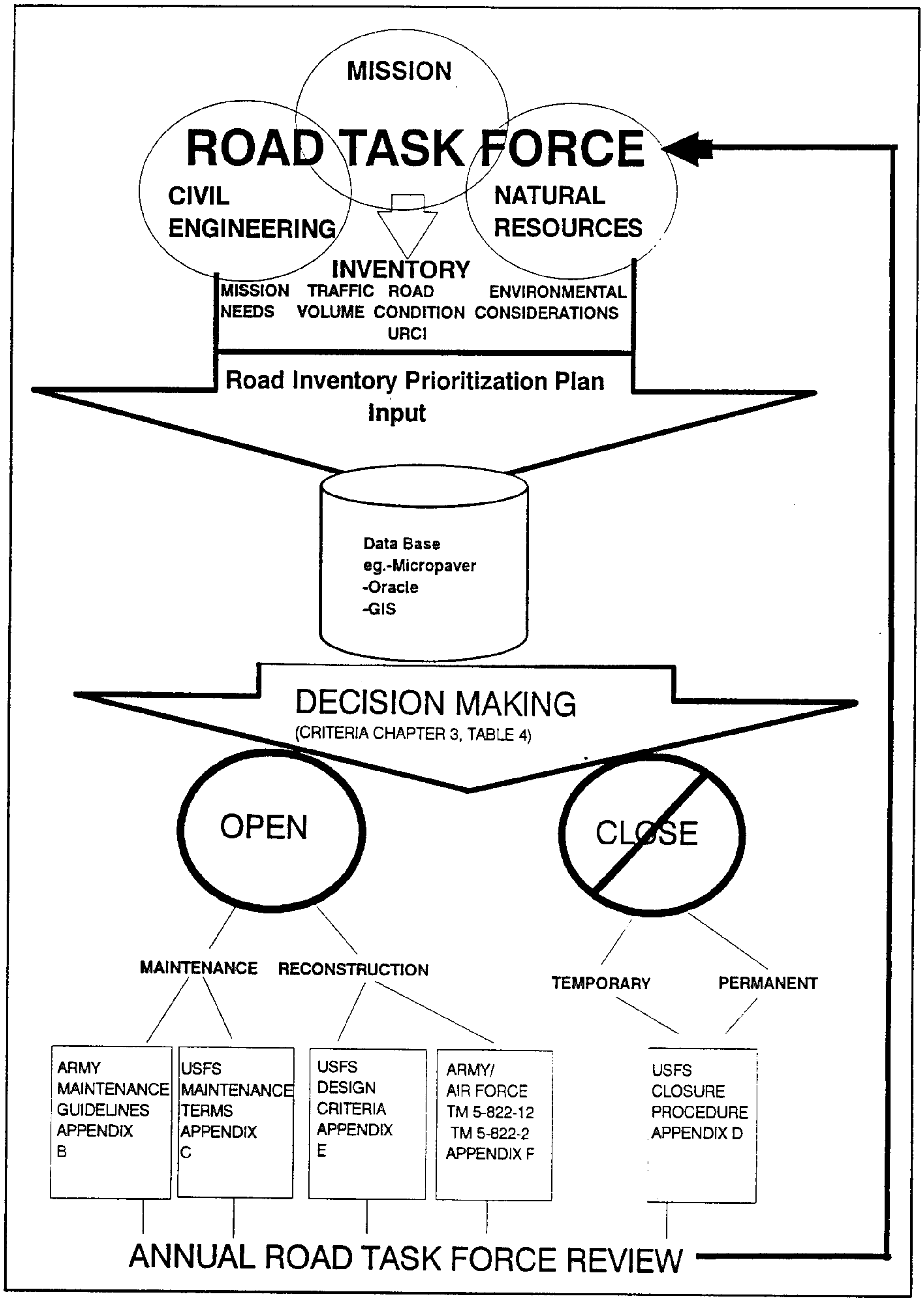


Figure 13. Flow chart

f. Closed roads fall into two classes, temporary or permanent. Appendix F presents USFS procedures for either choices.

g. On an annual basis, the task force should meet to re-evaluate the road system.

The road management focus of this effort has been to establish criteria to evaluate roads objectively for closure. The challenge is to reduce economic and ecological costs of unnecessary roads, which are causing ecological impacts to stream and wetland habitats. Economically, closing a road may cost one-fourth the amount required to maintain or reconstruct it (Webb Appendix A). The actions of a Task Force that meets regularly to discuss modifications to the Prioritization Plan and Road-Management Plan can serve as a model for other military installations faced with the problem of road management.

7 References

Brademas, James D. (1989). *Guidelines for Facilitators Conducting Nominal Group (NGT) Meetings,* Office of Recreation and Park Resources, University of Illinois, Urbana-Champaign.

Delbecq, A. L., Van de Ven, A. H., and Gustafson, D. H. (1975). *Group Techniques for Program Planning*, Scott, Foresman, and Co., Glenview, IL.

Eaton, R. A., and Beaucham, R. E. (1992). "Unsurfaced road maintenance management," Special Report 92-26, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH.

Hardesty, J. L., and Murin, S. L. (1994). Science in Support of Ecosystem Management, Summary of the First Annual Scientific Meeting, Eglin Air Force Base, Florida, The Nature Conservancy and Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL, 35 p.

Headquarters, Department of the Army. (1990). "Design of aggregate surfaced roads and airfields," Technical Manual TM 5-822-12, Washington, DC.

Headquarters, Departments of the Army and the Air Force. (1994). "Soil Stabilization for Pavements," Technical Manual TM 5-822-14/ AFMAN 32-8010, Washington, DC.

Headquarters, Departments of the Army and the Air Force. (1987). "General provisions and geometric design for roads, streets, walks, and open storage areas," Technical Manual TM 5-822-2/AFM 88-7, Chap. 5, Washington, DC.

Patrick, D. M., Brown, J. W., and Albertson, P. E. In review. Near-Surface Geology and Geohydrology of Eglin Air Force Base, Florida.

Patrick, D. M., Corcoran, M. K., Albertson, P. E., and Smith, L. M. (1994). Earth Resources Stewardship at Department of Defense Installations, Interim Report of the Earth Resources Task Area, Legacy Resources Management Program: Technical Report GL-94-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 143 p.

Patrick, D. M., Albertson, P. E., and Smith, L. M. (1994). Legacy Earth Resource Workshop, Proceedings of the March 1993 Earth Resource Workshop, Eglin Air Force Base, Florida, Miscellaneous Paper GL-94-12, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 40 p.

U.S. Department of the Air Force (USAF). (1993). Natural Resources Management Plan, Eglin Air Force Base, Florida, Plan Period: March 1993 - March 1997, HQ 646th Air Base Wing (AFMC), Eglin Air Force Base, FL.

Appendix A
Assessment of Observed Road Conditions - William R. Webb 1993

Assessment of Observed Road Conditions

During my field review on November 15, 1993, Steve Seiber and Mike Camizzi took me on a field trip to show me typical problems on various roads on the base.

These roads reflected several common characteristics:

a. The roads are old, well established travel ways that have abraded and eroded, thru time, to a point that the centerline grade is much lower than the surrounding ground on either side.

b. This depressed condition is resulting in excessive concentrations of surface water running down the road and ditch lines which result in water quality degradation at stream crossings.

c. There is little to no vegetation (grass) on road slopes to dissipate water velocity and reduce erosion.

d. Drainage structures and approach ditches at and above stream crossing are scarce and poorly maintained.

e. Fords are unprotected, there has been no attempt to provide a dry and/or stabilized crossing during low water flows.

f. There has been little to no attempt made to close or obliterate roads that apparently have minimal value to the transportation system.

Efforts have been made to disperse surface water runoff from the ditches with the use of wing ditches, this method is effective only when the road ditch will daylight in a reasonable distance to provide free out flow of water. In

many areas, the road and ditches were too low to allow the wing ditches to function properly.

The only solution to this problem is major reconstruction of all roads that are necessary to the mission of the base, timber operations or the recreating public.

a. Reconstruction will raise the road template to an elevation that will allow proper surface drainage and installation of new culvert cross drains.

b. Slopes must be flattened and stabilized to reduce future maintenance costs.

c. An integral part of the reconstruction must be vegetation to protect both the road and water quality.

Closure of selected roads by placing individual roads in "care status" and putting the road "to bed" thru gateing, draining, revegetating, and signing until its next required use will also reduce water quality degradation.

Obliteration of all remaining roads that are not necessary to the mission of the base, timber operations or the recreating public will drastically reduce water quality degradation. Generally, all these roads are contributing to environmental degradation and the cost effectiveness of reconstruction of non-essential roads will be cost prohibitive.

Note

All options are expensive, but necessary to prevent future water quality degradation. None of the options fall within the realm of normal or routine road maintenance because of the excessive costs that have accrued thru years of use and weathering with little to no effort or funds expended in previous years.

Costs of Road Reconstruction and Closure

The following costs will be average unit costs per mile that are directly affected by terrain, drainage, and degree of deterioration of the travel way.

a. Road reconstruction.

(1) Single lane $25-50,000 per mile.

(2) Double lane $30-60,000 per mile.

(3) Rock surfacing will add an additional $10-15,000 per mile.

b. Road Closure.

(1) Obliteration.

Average Road	$5-20,000 per mile.

(2) Care status.

Average Road	$10-25,000 per mile.

Road Maintenance

All surface blading road maintenance should be accompanied by a vibratory steel wheel roller or a rubber tired traffic roller to compact the freshly bladed surface. This will preserve the existing surfacing, time, and money invested in the blading operation. Time between bladings can be increased two fold or more depending on weather conditions immediately following the blading.

Wm. R. Webb

William R. Webb
C.E.

Road Log and Inventory

The most logical starting point in managing a transportation system is an inventory of the system as it exists on the ground.

The inventory must consist of reliable, legible maps, and an accurate record of the existing roads.

The road log is an accurate description of the road and its existing features:

a. *Identification*. Road number or letter to identify the road on both the map and the ground.

b. *Termini*. Beginning and ending points of identified road.

c. *Length*. Actual length of road.

d. *Width*. Desired width of road and existing width.

e. *Surfacing*. Type of wearing surface on road - soil or improved, stabilized material and points on the road where it changes in character.

f. *Pertinent Features*. Located by wheel log or calibrated odometer as mile post points.

(1) *Width*. Width of road as it changes on the ground, i.e. single lane, double lane, turnout, etc.

(2) *Drainage*. Location, type, size, length and condition of each drainage feature, i.e. bridge, culvert, road ditches, wing ditches, berms, etc.

g. Additional data that may be pertinent is: county lines, maintenance responsibility, ultimate use or disposition of road.

(See Sample "Road Log" Sheet for Format)

ROAD LOG

FOREST ______________________ TERMINI: FROM ______________ TO ______________
ROAD NAME & NO. ______________________ LENGTH ______________
RANGER DISTRICT ______________________ SURFACE - TYPE (S) ______________ THICKNESS ______________
INVENTORIED BY ______________ DATE ______________ REVISED BY ______________ DATE ______________

MILE POST	WIDTH	SHOULDERS	TURNOUTS		DITCH		CULVERTS			BRIDGE INV. NO.	OTHER STRUC-TURES	SIGNS SIZE,TYPE (MUTCD)	TYPE GUARDRAIL		OTHER
			L	R	L	R	SIZE	TYPE	LENGTH				L	R	
TOTALS															

Road Log

Appendix B
U.S. Army CRREL (26-92) Unsurfaced Road Maintenance Management
Chapter 4 Maintenance and Repairs Guidelines

CHAPTER 4
MAINTENANCE AND REPAIR (M&R) GUIDELINES

4-1. Introduction

M&R requirements and priorities are highly related to the URCI, since the URCI is determined by distress information. This chapter describes how to do an unsurfaced road evaluation, how to determine feasible M&R alternatives, and how to establish M&R priorities.

4-2. Unsurfaced road evaluation procedure

Evaluation is done section by section, since each section represents a unit of the unsurfaced road network that is uniform in structure and subjected to consistent traffic loadings. It is necessary to comprehensively evaluate surface condition before feasible M&R alternatives can be rationally determined.

a. Overall condition. The URCI of an unsurfaced road section describes the section's overall condition. In turn, the overall condition of the section correlates highly with the needed level of M&R.

b. Variations of the URCI within a section. The URCI can vary within a section, either randomly localized or systematically. When a URCI value of a sample unit in the section is more than 10 points less than the sample unit average URCI value, a localized random variation exists. This variation should be considered when determining M&R requirements. Systematic variation occurs whenever a large, concentrated area of a section has a significantly different condition. For example, if traffic is channeled into a certain portion of a large parking lot, that portion may show much more distress or be in a poorer condition than the rest of the area. Whenever a significant amount of systematic variability exists within a section, the section should be subdivided into two or more sections.

c. Rate of deterioration. Both the long- and short-term rate of deterioration of each unsurfaced road section should be checked. The long-term rate is measured from the time of construction or time of last overall M&R (such as regrading).

d. Distress evaluation. Examination of the specific distress types, severities, and quantities present in a road section can help identify the cause of surface deterioration, its condition, and eventually its M&R needs.

4-3 Comprehensive maintenance program

Following are five steps used to establish a comprehensive maintenance program for unsurfaced roads:

- Surveying the road network (step one).
- Establishing a road condition index (step two).
- Setting maintenance priorities (step three).
- Determining maintenance alternatives (step four).
- Calculating actual maintenance costs (step five).

a. Step one: Survey the road network. Survey all roads within the network and divide them into branches, sections, and sample units as described in chapters 2 and 3. Branches are a single area, such as a road or parking lot. A section is a division of a branch with consistent characteristics of:

- Structure.
- Traffic.
- Construction history.
- Road rank.
- Drainage and shoulders.

A sample unit, the smallest division, is generally a 100-foot-long segment of a section and is the area consistently surveyed and used for determining the road condition. *Ideally, an inspector should conduct a "windshield inspection" of the entire road network once each season* (four times a year), and a detailed inspection of the sample units annually. *NOTE*: Dividing the road network is a one-time requirement, after which minor adjustments are made as needed.

b. Step two: Establish the unsurfaced road condition index (URCI). Rate the sample unit with the seven distresses and the severity level of *low, medium or high* for each. The distresses are listed below and shown in figure 4–1.

- 81. Improper cross section.
- 82. Inadequate roadside drainage.
- 83. Corrugations.
- 84. Dust.
- 85. Potholes.
- 86. Ruts.
- 87. Loose aggregate.

The URCI is used to determine the extent and magnitude of road problems and the M&R required. A reproducible URCI rating inspection sheet is shown in figure C–1.

c. Step three: Establish maintenance priorities. Set priorities for maintenance by using figure 4–2. The maintenance priority is set by a combination of the URCI and the amount of traffic per day on the road.

- *Category I* road has more than 200 vehicles per day (vpd)
- *Category II* has 100 to 199 vpd
- *Category III* has 50 to 99 vpd

• *Category IV* has 0 to 49 vpd.

Find the surveyed road's URCI rating number on the left side of figure 4–2. *The lower the URCI and the higher the traffic volume, the greater the priority.* If the URCI rating is below the solid line for that traffic category, the priority is highest. All roads within the network can then be rated as low, medium, or high priority based upon road category, the budget, and local practice. *Maintaining a road with a high URCI rating is less expensive than rebuilding a failed road.*

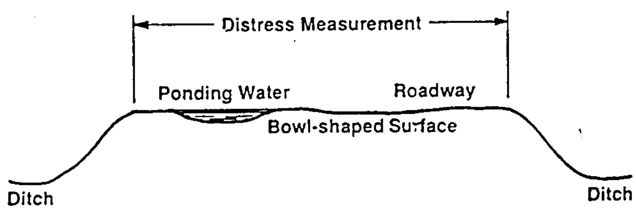
(1) The criteria for establishing priorities for road sections where routine M&R is required are different from those used for sections that need major M&R.

(2) Priorities for sections requiring routine M&R are a function of existing individual distress types and severities. A single method is usually applied for a given area, which may consist of many sections, rather than different M&R methods for one section. Distresses that may have a considerable negative effect on the section's operational performance are usually corrected first. For example, medium- and high-severity bumps, corrugations, and potholes would usually receive high priority.

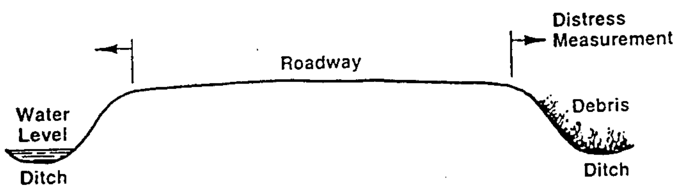
(3) Priorities among sections requiring major M&R are a function of the overall section condition, as reflected in the URCI, traffic, and management policies. For example, a decision might be made to repair all primary roads with a URCI of less than 50, secondary roads with a URCI of less than 40, and parking lots with a URCI of less than 30. The above URCI limits are provided as an example. Local conditions at Army installations and commands will dictate what actual values to use.

(4) The priority for maintenance can remain flexible. Physical catastrophes such as floods or severe storms or immediate safety defects demand immediate repairs. The completion of previously started projects or the addition of outside funding can also affect the priorities.

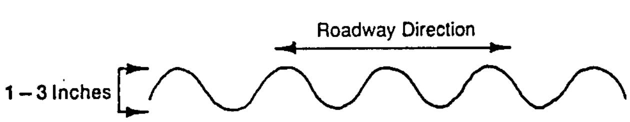
d. Step four: Determine maintenance alternatives. In the process of selecting feasible alternatives, one of the



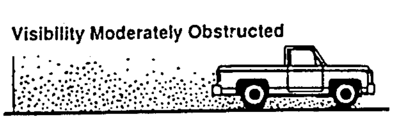
a. Improper cross section (81).



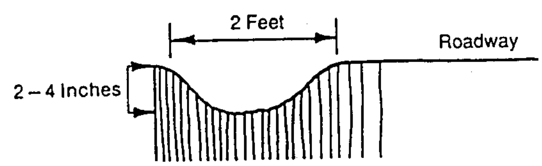
b. Inadequate roadside drainage (82).



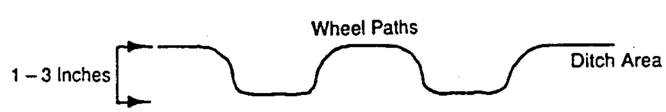
c. Corrugations (83).



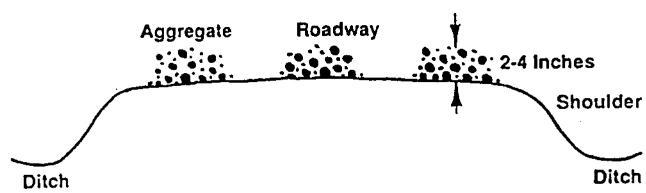
d. Dust (84).



e. Potholes (85).



f. Ruts (86).



g. Loose aggregate (87).

Figure 4–1. Medium severity distresses.

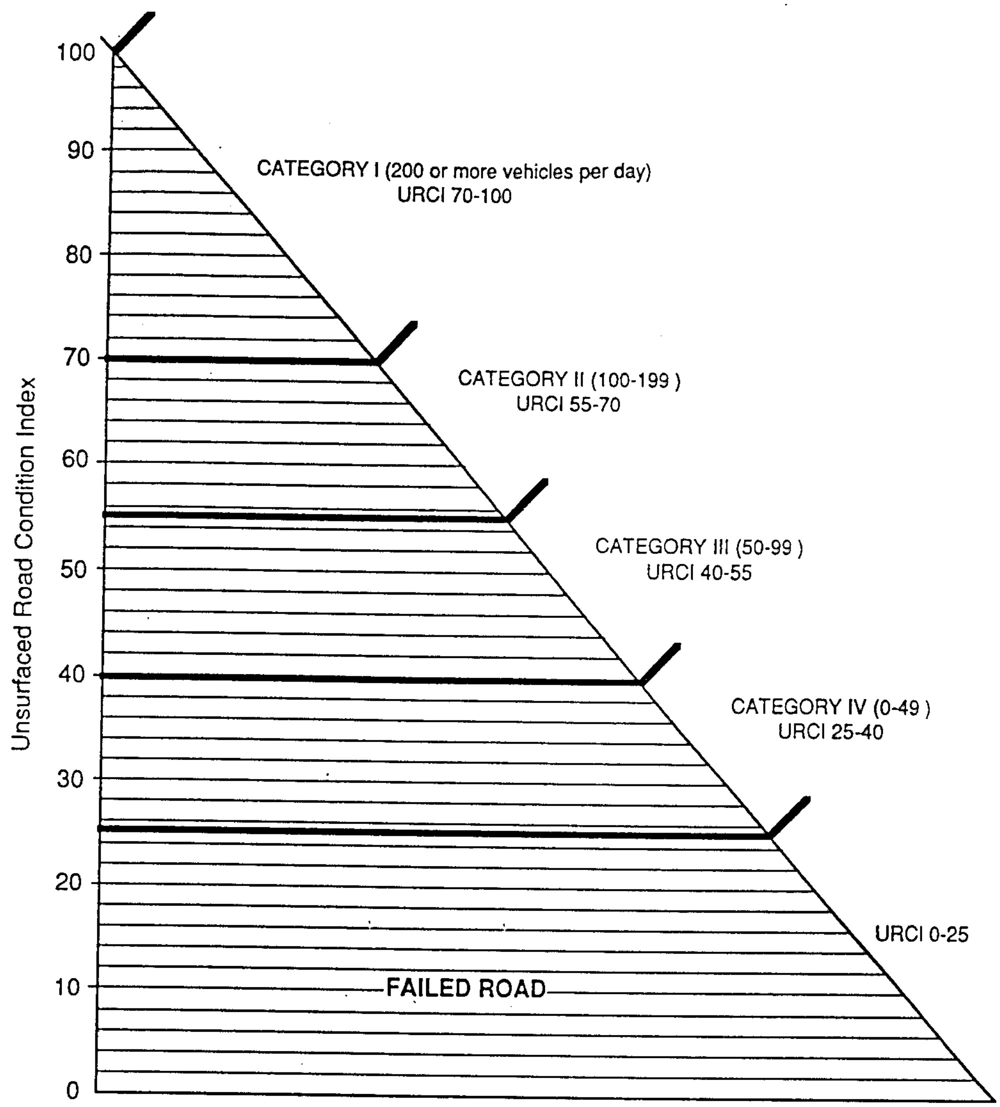


Figure 4–2. Maintenance priority graph.

primary assumptions is that the strategy will be implemented within 2 years. The process of selecting feasible M&R alternatives is described below.

(1) *Determine M&R strategy.*

(a) The purpose of this step is to identify the road sections that need comprehensive analysis. The data required for the identification are the URCI, distress, road rank, road usage, traffic, and management policy.

(b) Based on the factors in subparagraph 4–3d(1)(a) above, a limiting URCI value is established for each type of road: e.g., 70 for primary roads with traffic volume exceeding 200 vehicles per day. If a road has a URCI above the limiting value, continuation of existing maintenance policy is recommended unless review of the distress data shows that the majority of distress is caused by inadequate road strength or if the rate of surface deterioration is thought to be high, or both.

(c) If the M&R strategy decision is to continue existing maintenance policy, the information in table 4–1 is used as a guide to select the appropriate maintenance method. This table presents feasible maintenance methods for each distress type at a given severity level.

(2) *Determine feasible M&R alternatives based on the branch condition evaluation summary* (see fig E–3).

(a) The purpose of this step is to determine whether alternatives other than existing maintenance policy should be considered (e.g., paving or sealing), and, if so, what specific feasible alternatives to consider. This is done by analyzing the section evaluation sum-

Table 4–1. Maintenance alternatives.

Distress	*Severity code*	*Cost code**	*Description*
81 Improper cross section	L	B	Grade only
	M	B/C	Grade only/grade and add material (water or aggregate or both), and compact. Bank curve. Adjust transitions.
	H	C	Cut to base, add aggregate, shape, water, and compact.
82 Improper roadside drainage	L	B	Clear ditches every 1–2 years.
	M	A B	Clean out culverts. Reshape, construct, compact or flare out ditch.
	H	C	Install underdrain, larger culvert, ditch dam, rip rap, or geotextiles.
83 Corrugations	L	B	Grade only.
	M	B/C	Grade only/grade and add material (water or aggregate or both), and compact.
	H	C	Cut to base, add aggregate, shape, water, and compact.
84 Dust stabilization	L	C	Add water.
	M	C	Add stabilizer.
	H	C	Increase stabilizer use. Cut to base, add stabilizer, water, and compact. Cut to base, add aggregate and stabilizer, shape, water, and compact.
85 Potholes	L	B	Grade only.
	M	B/C	Grade only/grade and add material (water, aggregate or 50/50 mix of calcium chloride and crushed gravel), and compact.
	H	C	Cut to base, add aggregate, shape, water, and compact.
86 Ruts	L	B	Grade only.
	M	B/C	Grade only/grade, add material, and compact.
	H	C	Cut to base, add aggregate, shape, water, and compact.
87 Loose aggregate	L	B	Grade only.
	M	B/C	Grade only/grade, add material and compact.
	H	C	Cut to base, add aggregate, shape, water, and compact.

*Cost code guide: A = labor, overhead; B = labor, equipment, overhead; C = labor, equipment, materials, overhead.

mary (fig 4–3) for the pavement section under consideration. Based on this analysis, existing maintenance would usually be recommended except when one or more of the following conditions exists:

- Long- or short-term rate of road deterioration is high.
- Load-carrying capacity is deficient.
- Load-associated distress accounts for a majority of the distress deduct value.
- Surface roughness is rated major.
- A change in mission requires greater load-carrying capacity.

(b) Table 4–1 lists most of the available overall repair procedures for unsurfaced roads.

(c) All feasible alternatives should be identified based on a careful analysis of the section evaluation summary (see fig E–4). Life-cycle cost analysis of the feasible alternatives will help rank the alternatives based on cost, and thus provide necessary information for selecting a cost-effective M&R alternative.

(3) *Determine maintenance alternatives.* Do this by looking up the distress type and the severity code in table 4–1.

(a) The problem or *distress* is listed in the left hand column. It is followed by the *severity level*. Simply locate the applicable distress and severity level and follow it across the page to the *description* column. The maintenance alternatives are given there. The cost guide is useful in determining the amount of labor, material or equipment needed for each alternative. A description of costs involved in each code is listed at the bottom of the table.

Street/Road	Date			
Distress	Severity Level	L.	M.	H.
Maintenance Alternative	Priority	L.	M.	H.
Cost Code A. B. C.				

	Labor*	Equipment	Materials**	Contract	Estimated Total	Actual Total
Cost Code A	x				x	x
Your Costs						
Your Overhead						
		Total (including overhead)				

	Labor*	Equipment	Materials**	Contract	Estimated Total	Actual Total
Cost Code B	x	x			x	x
Your Costs						
Your Overhead						
		Total (including overhead)				

	Labor*	Equipment	Materials**	Contract	Estimated Total	Actual Total
Cost Code C	x	x	x	x	x	x
Your Costs						
Your Overhead						
		Total (including overhead)				

*Total Costs are: Hourly rates times the number of hours.
(example: $250/hr x 10hrs = $2500)
**Material costs are your in-place costs for gravel, water, culverts, geotextiles, etc.

Figure 4–3. Cost calculation sheet.

ROAD (list by priority rating: highest to lowest)	Category	Existing URCI	Total funds available for maintenance	Estimated cost to upgrade to 70 URCI	Balance
FARM RD.	1	65	$50,000	$2,500	$47,500
SHAW RD.	3	36	$47,500	$16,500	$31,000
LEE RD.	2	57	$31,000	$4,000	$27,000
ALAN RD.	4	28	$27,000	$20,000	$7,000
FRENCH RD.	3	46	$7,000	$12,000	-$5,000
BRIAR LANE	2	58	——	$9,000	UNFUNDED
SPRINGHOUSE	3	45	——	$10,000	UNFUNDED

Figure 4–4. Yearly maintenance record.

(b) For example, use *Potholes*. Low severity—*Grade only*—cost code *B* indicates labor, equipment and overhead costs are involved:

85 Potholes	L	B	Grade only
	M	B / C	Grade only / grade and add material (water, aggregate, or 50/50 mix of (calcium chloride and crushed gravel), and compact
	H	C	Cut to base, add aggregate, shape, water, and compact.

(c) It is important to recognize that drainage problems are usually the basic cause of a number of distresses. Corrugations, potholes and ruts, while corrected by grading, may have been created because a road does not drain properly. Therefore, adequate drainage both on, and beside, the road must be addressed to eliminate or decrease future distresses and cut down on the amount of grading needed to properly maintain a road. *Adequate drainage is always necessary.*

e. Step five: Calculate actual maintenance costs. Using the sample Cost Calculation Sheet (fig 4–3), find the appropriate cost code line, put the actual cost figures in the appropriate boxes, and find the total needed to complete the necessary maintenance. A reproducible copy of the sheet is located in appendix E (fig E–6).

(1) Figure 4–3 can give you a reasonable cost estimate to repair a certain road. It can then be used to decide where a limited budget will be spent or to set the final maintenance schedule. After completion of the job, actual costs may be inserted and it can serve as a record of how funds were spent.

(2) The final chart is the Yearly Maintenance Record (fig 4–4). A reproducible copy of the table may be found in appendix E (fig E–7). List all roads by priority with the *highest priority first, lowest last.* For road 1 (greatest priority) enter *total* funds available in column 3. Put the estimated cost to upgrade that road in column 4. By subtracting the amount needed (col 4) from the amount available (col 3) one can easily see the *balance* remaining. That balance now becomes the *total* available for the next road. Enter that amount in column 3 for the second road. Put in the estimated cost to repair the second road and subtract again. The new balance is entered in the available funds column for the third road. Repeat this process until all the available funds are used. When the balance is at $0.00, all required maintenance that is currently unfunded is easily seen. This enables allocation of money more effectively and, if necessary, justification of requests for additional funds.

Appendix C
U.S. Forest Service Maintenance Terms

Road Maintenance

The performance of work activities needed to preserve or protect a roadway including surface, shoulders, roadside, structures, and such traffic-control devices as are necessary for its safe and efficient use to the standard provided through construction, the most recent reconstruction, or other condition as agreed.

Road maintenance level

The five road maintenance levels are as follows:

a. *Level 1.* Assigned to intermittent service roads during the time they are closed to vehicular traffic. Basic custodial maintenance is performed to keep damage to adjacent resources to an acceptable level and to perpetuate the road to facilitate future management activities.

b. *Level 2.* Assigned to roads open for use by high clearance vehicles. Passenger car traffic is not a consideration.

c. *Level 3.* Assigned to roads open and maintained for travel by a prudent driver in a standard passenger car. User comfort and convenience are not considered priorities.

d. *Level 4.* Assigned to roads that provide a moderate degree of user comfort and convenience at moderate travel speeds.

e. *Level 5.* Assigned to roads that provide a high degree of user comfort and convenience.

Recurrent Maintenance

Work that is needed on a continuing basis with accomplishment annually or more frequently.

Deferred Maintenance

Work that is deferred 1 or more years until such time as the work is needed or can be economically or efficiently performed.

Traffic Generated Maintenance

Work, except repair of Major Damage, made necessary as a direct result of, or to minimize the effect of, use and wear by traffic.

Non-Traffic Generated Maintenance

Work made necessary as a direct result of normal weathering processes or uncontrollable influences that cannot be attributed to traffic use.

Major Damage

Damage resulting from:

a. Natural causes that is not repairable by normal maintenance practices; considered in excess of that normally occurring for the area; and not anticipated or provided for in the Annual Maintenance Plan.

b. Road use that intentionally or unintentionally affects serviceability of the road or results in wear or damage in excess of that occurring in the area under normal operating conditions and procedures.

Restoration

Work necessary, as a result of major damage, to restore a road to the standard and serviceability that existed prior to the damage.

Annual Maintenance Plan

The Annual Maintenance Plan will include the anticipated recurrent and deferred road maintenance work needed during the calendar year. It shall include a 5-year projection of deferred maintenance work envisioned on roads.

The Annual Maintenance Plan will include, as a minimum, estimates of the following information:

a. Road number and segments or groups of roads.

b. Length in miles.

c. Planned maintenance, by traffic generated and non-traffic generated categories.

d. Shares of non-traffic generated work attributable to each party.

e. Shares of traffic generated work based on EU's attributable to each party.

f. Performance responsibility and credits for each party.

g. A summation of the total traffic and non-traffic generated maintenance obligation for each party for the year.

h. For each jointly owned road or group of roads, an accounting of the cumulative traffic by each party since original construction/ reconstruction or the most recent surface rock replacement or since all traffic generated deferred maintenance obligations were last reconciled and satisfied.

The above information will be estimated and documented at the annual cost share maintenance planning meeting and reconciled for actual work performed and road use at the year-end closeout for each calendar year.

Appendix D
U.S. Forest Service Closure Procedures

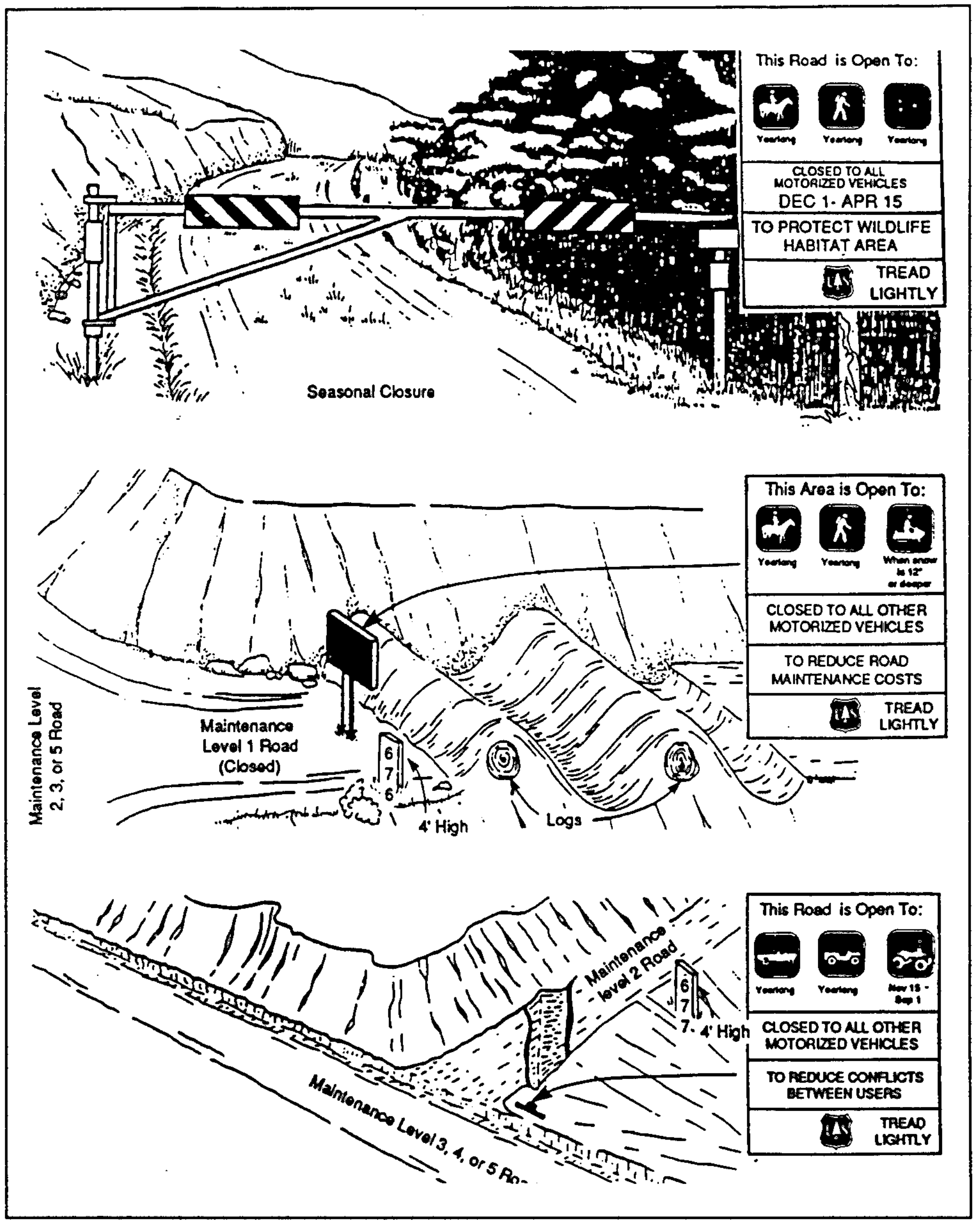
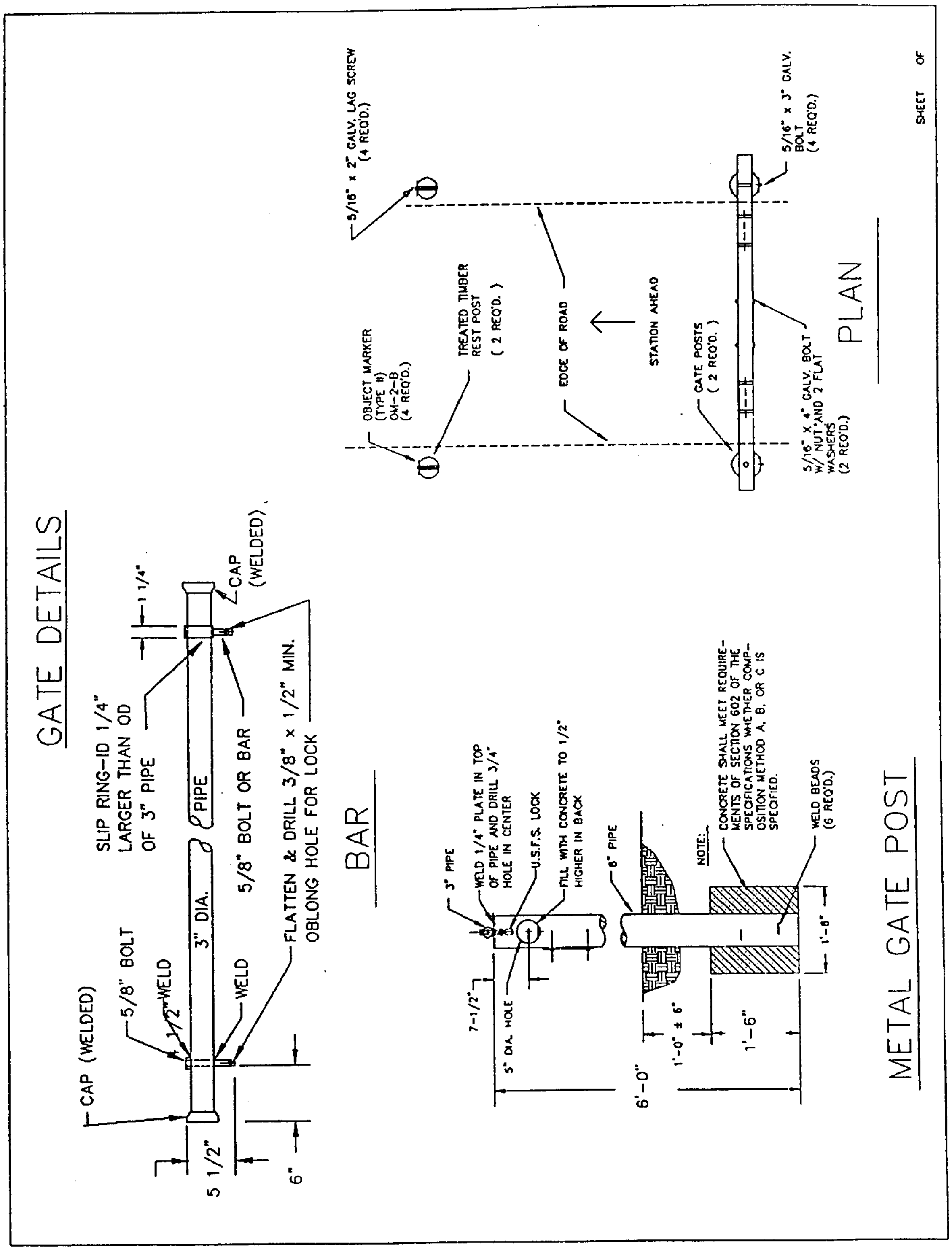
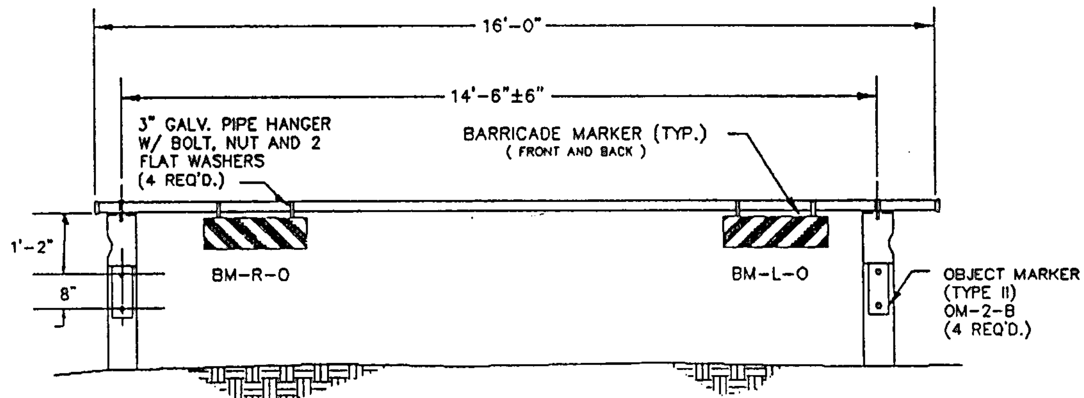


Figure D1. Entrance treatments for restricted travel in national forest areas, roads, and trails


GATE DETAILS
CAP (WELDED)
5/8" BOLT
WELD
1/2"
3" DIA.
WELD
5 1/2"
6"
FLATTEN & DRILL 3/8" x 1/2" MIN.
OBLONG HOLE FOR LOCK
5/8" BOLT OR BAR
PIPE
SLIP RING—ID 1/4"
LARGER THAN OD
OF 3" PIPE
1 1/4"
CAP
(WELDED)
BAR
3" PIPE
WELD 1/4" PLATE IN TOP
OF PIPE AND DRILL 3/4"
HOLE IN CENTER
U.S.F.S. LOCK
FILL WITH CONCRETE TO 1/2"
HIGHER IN BACK
6" PIPE
7-1/2"
5" DIA. HOLE
NOTE:
CONCRETE SHALL MEET REQUIRE-
MENTS OF SECTION 602 OF THE
SPECIFICATIONS WHETHER COMP-
OSITION METHOD A, B, OR C IS
SPECIFIED.
WELD BEADS
(6 REQ'D.)
1'-8"
6'-0"
1'-0" ± 6"
1'-6"
METAL GATE POST
5/16" x 2" GALV. LAG SCREW
(4 REQ'D.)
OBJECT MARKER
(TYPE II)
OM-2-B
(4 REQ'D.)
TREATED TIMBER
REST POST
(2 REQ'D.)
EDGE OF ROAD
STATION AHEAD
GATE POSTS
(2 REQ'D.)
5/16" x 3" GALV.
BOLT
(4 REQ'D.)
5/16" X 4" GALV. BOLT
W/ NUT AND 2 FLAT
WASHERS
(2 REQ'D.)
PLAN
SHEET OF

GATE DETAILS



ELEVATION

NOTES:

1. INSTALLATION SHALL CONSIST OF 2 METAL GATE POSTS, 1 BAR WITH ALL ATTACHMENTS, 2 TREATED TIMBER REST POSTS ALL HARDWARE AND SIGNS. FOREST SERVICE WILL FURNISH LOCKS. CONTRACTOR SHALL FURNISH ALL OTHER MATERIALS.

2. METAL GATE POST SHALL BE NON-GALVANIZED STANDARD WEIGHT 6" DIA. IRON OR STEEL PIPE (18.97 LBS./FT.). WELL CASING IS ACCEPTABLE. BAR SHALL BE NON-GALVANIZED STANDARD WEIGHT 3" DIA. IRON OR STEEL PIPE (7.58 LBS./FT.). 6" DIA. X 5' TREATED TIMBER REST POSTS TO BE "V" NOTCHED ON TOP.

3. ALL MATERIAL SHALL BE FREE OF RUST. ALL WELDS AND CUTS SHALL BE REASONABLY SMOOTH.

4. LOWER 12" OF POST SHALL RECEIVE 6 RANDOM WELD BEADS APPROXIMATELY 1/2" IN LENGTH TO INSURE BONDAGE TO CONCRETE.

5. METAL GATE POSTS AND BAR SHALL RECEIVE 1 COAT OF RUST CONTROL PRIMER (SHERWIN-WILLIAMS #A57R17 OR EQUAL), AND 2 COATS OF ENAMEL PAINT (SHERWIN-WILLIAMS "WHITE" S-H #S65W3 OR EQUAL).

6. BARRICADE MARKERS TO BE ATTACHED ON BAR WITH GALVANIZED PIPE RINGS, BOLTS, NUTS AND 2 FLAT WASHERS.
OBJECT MARKERS TO BE ATTACHED ON TREATED TIMBER REST POSTS WITH GALVANIZED LAG SCREWS.
OBJECT MARKERS TO BE ATTACHED ON METAL GATE POSTS WITH GALVANIZED BOLTS DURING THE FILLING OF GATE POST WITH CONCRETE OR ATTACHED WITH ANCHOR BOLTS IF THE GATE POST HAS PREVIOUSLY BEEN FILLED WITH CONCRETE.
ALL BOLTS ARE TO BE PEENED OR MUSHROOMED AFTER INSTALLATION TO PREVENT REMOVAL OF SIGNS.
ALL GATE WORK INCIDENTAL TO PAY ITEM 640(01).

SHEET____OF____

Appendix E
U.S. Forest Service Design Criteria and Roadway Drainage

Design implies the concept of alternative solutions. Use engineering judgment to evaluate alternatives to best fit the project objectives.

Good designs are never attained by simply knowing and rigidly applying techniques or automated systems. Use the system most suited to the particular project. These include various computer aided systems, hand design, field design, and flagline. A combination of systems may be appropriate for a single road project.

The Air Force is not a public road authority; therefore, there is an opportunity to control both the using vehicle and the road design. However, roads that are open to the public and are passable by standard four-wheel passenger cars are subject to the requirements of the Highway Safety Act.

Objective

To meet the design criteria through proper selection and application of design elements and standards.

Definitions

Design criteria. Those requirements that govern selection of elements and standards for a road or section of road.

Design elements. The physical characteristics of a road (such as traveled-way width, shoulders, slopes, curve widening, and pavement structures) that, when combined, comprise the planned facility.

Design standards. The definitive lengths, widths, and depths of individual elements (such as 14-ft traveled way, 2-ft shoulders, 2:1 cut slopes, 3-ft curve widening, and 6 in. of crushed aggregate).

Design Criteria

This section discusses design criteria and how they function as a decision basis for the selection and application of elements and standards.

Environmental and resource considerations

These considerations may define the limits of the traveled way, identify sensitive soils areas, identify wildlife and fisheries sensitivities, indicate needed treatment on exposed surfaces and roadsides, and identify visual quality concerns. These include factors (such as topography, climate, and soils) that affect the alignment, gradients, sight distance, road template, slope selection, drainage, and pavement structure. Future recreational uses, such as trails for hiking and riding, may be indicated for roads to be closed to standard vehicular traffic.

Safety

Safety affects the selection of geometric elements and design speed, requires the examination of possible hazards and corrective actions needed, and identifies the needs for traffic control and maintenance activities.

Traffic requirements

The volume, composition, distribution, and whether the road is subject to the Highway Safety Act are elements of traffic criteria used in the design of turnouts, road widths, surfacing, safety features, and traffic control. The applicability of the Highway Safety Act is determined during transportation system planning.

Traffic service levels

Traffic service levels (TSL) describe a road's significant traffic characteristics and operating conditions. These levels are identified as a result of transportation planning activities.

Exhibit 1 contains descriptions of the four different traffic service levels (TSL) for Forest roads. These traffic service levels include the traffic characteristics that are significant in the selection of design criteria and describe the operating conditions for the road.

The levels reflect a number of factors, such as speed, travel time, traffic interruptions, freedom to maneuver, safety, driver comfort, convenience, and operating cost. These factors, in turn, affect design elements, such as:

a. Number of lanes.

b. Turnout spacing.

c. Lane widths.

d. Type of driving surface.

e. Sight distances.

f. Design speed.

g. Clearance.

h. Horizontal and vertical alignment.

i. Curve widening.

j. Turnarounds.

Vehicle characteristics

Vehicle characteristics describe the physical characteristics of vehicles using the road.

a. Design vehicle. The vehicle frequently using the road that determines the minimum standard for a particular design element. No single vehicle controls the standards for all the design elements for a road. Determine the maximum and minimum standards from the type and configuration of the vehicles using the road. Analyze each design element to determine which vehicle governs the standard for that element. Following are some examples:

Design Element	Possible Design Vehicle
Stopping sight distance	Passenger car or pickup
Thickness of pavement structure	
(1) Campgrounds truck	Garbage or other service
(2) Logging road	Yarding equipment or construction equipment
Curve widening	Lowboy or gravel truck
Lateral or vertical clearance	Yarding equipment
Gradient	Gravel truck or recreation vehicles

b. Critical vehicle.

(1) The vehicle, normally the largest (by weight, size, or unique configuration), whose limited use on the road is necessary to complete the planned activity.

Critical vehicle examples:

(a) Log yarder on a timber access road.

(b) Semitrailer truck carrying construction equipment on a recreation access road.

(c) Overlength, overwidth semitrailer trucks carrying drill rig components on a minerals access road.

(d) Construction equipment used to build the facility.

(e) Recreation vehicles, such as large motorhomes, with or without other vehicles in tow.

(2) Depending on the traffic service level of the road, special design provisions, operational considerations, or a combination of both may accommodate critical vehicles.

c. Design and critical vehicle analysis. Consider both the equipment needed to construct the road and the equipment that will use the completed road.

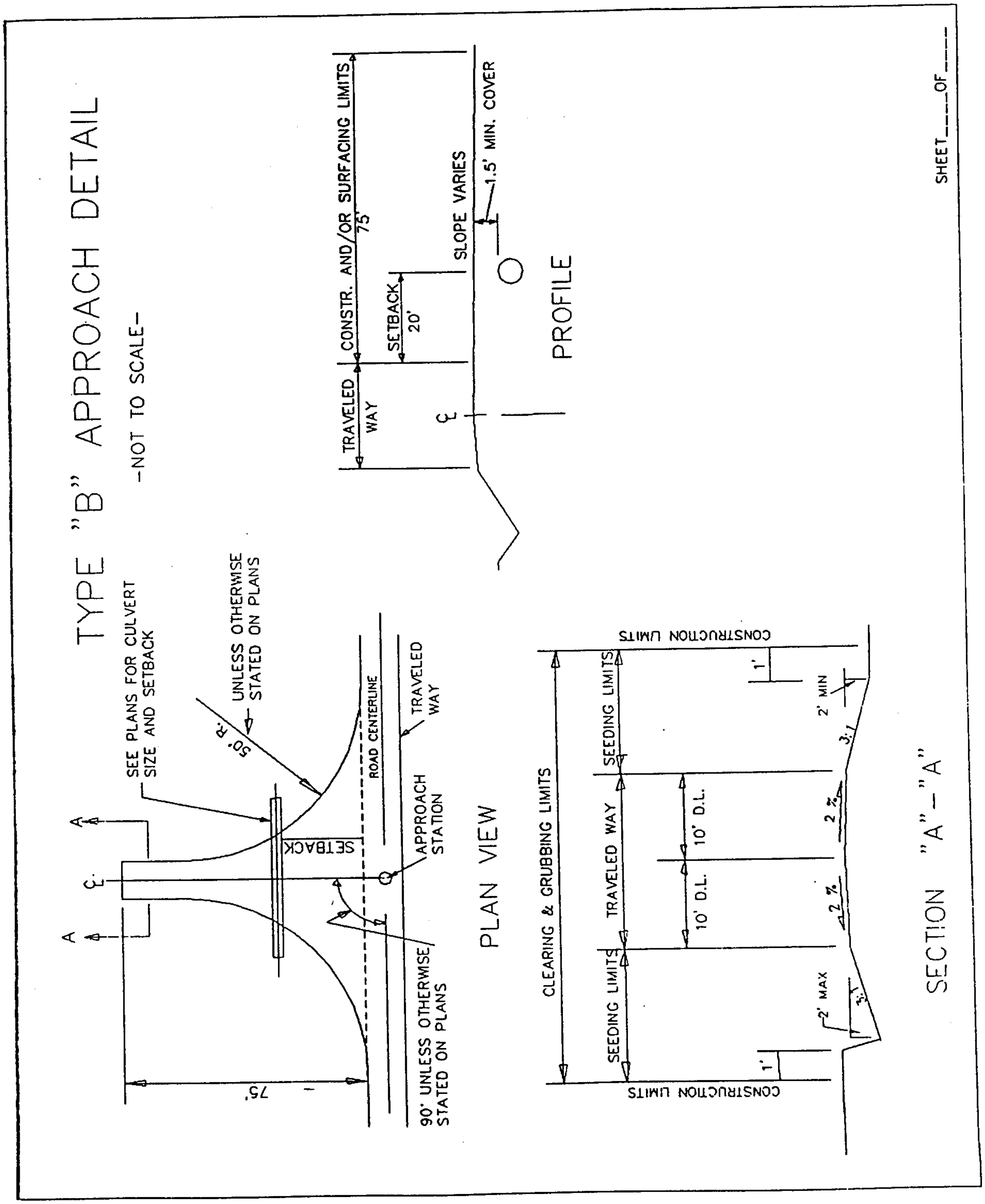
Road user

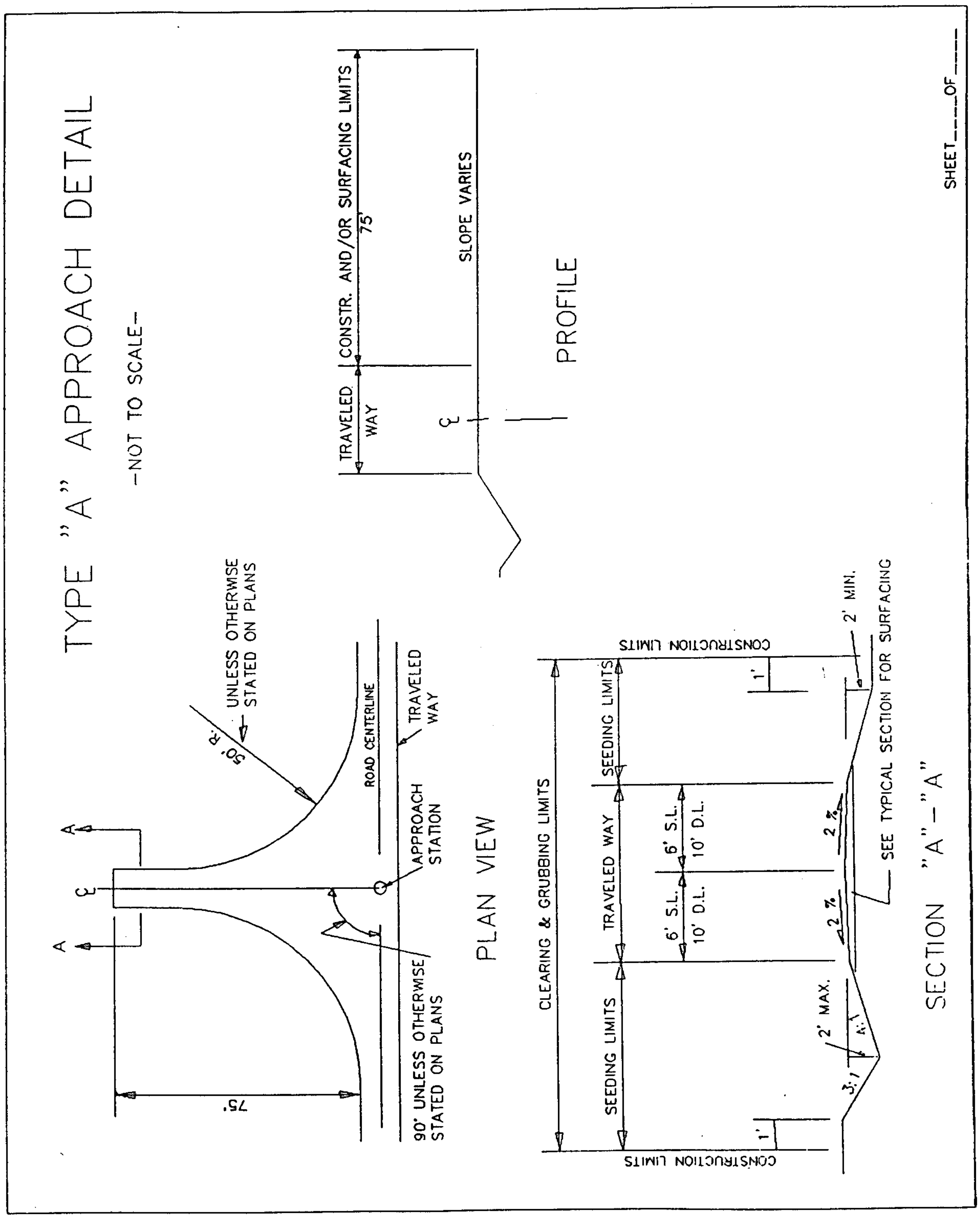
The selection of the design elements and standards should be based on a road user (design driver) who is considered to be a safe and prudent driver. This does not imply that all drivers are familiar with the type or environmental setting of the road.

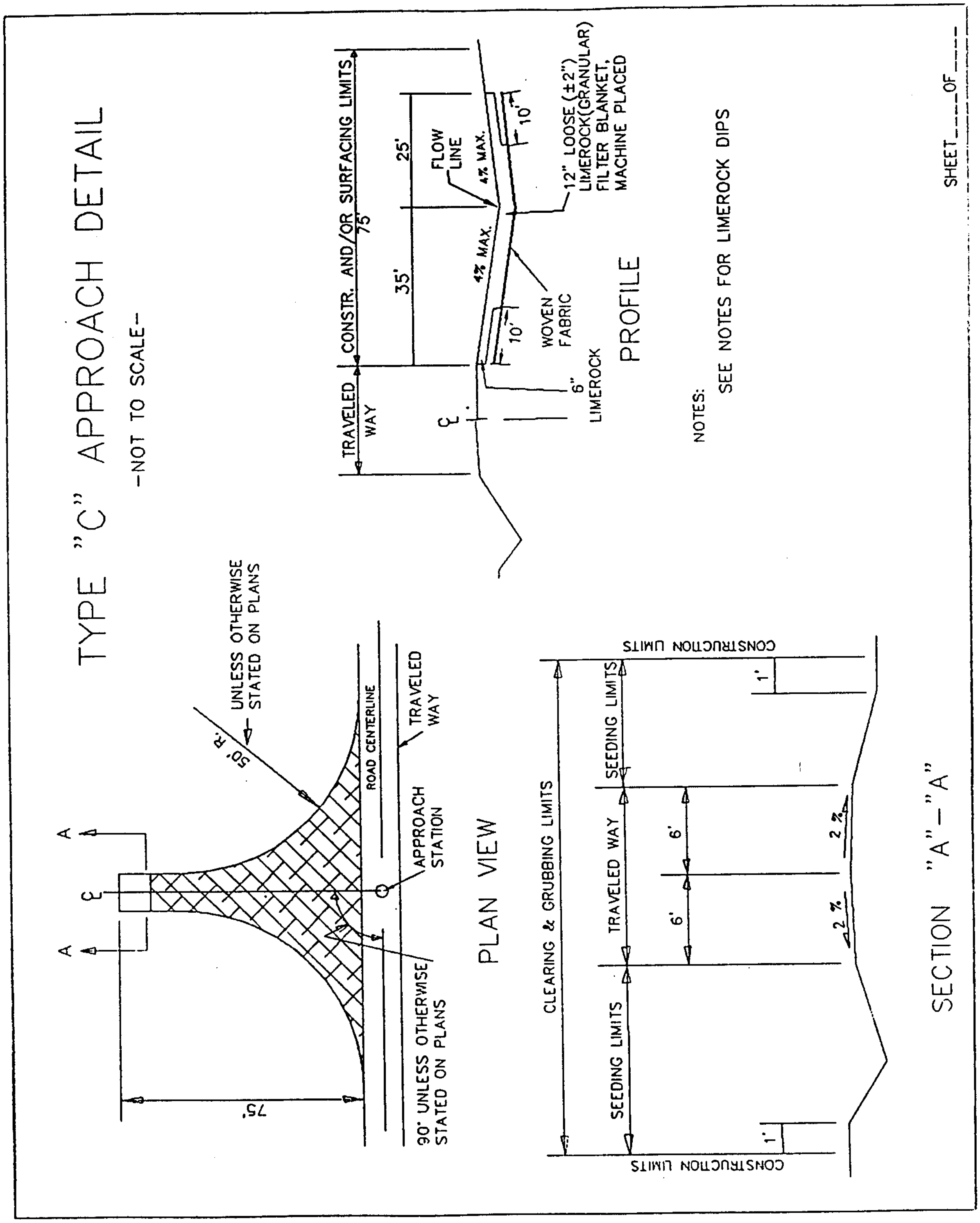
Economics

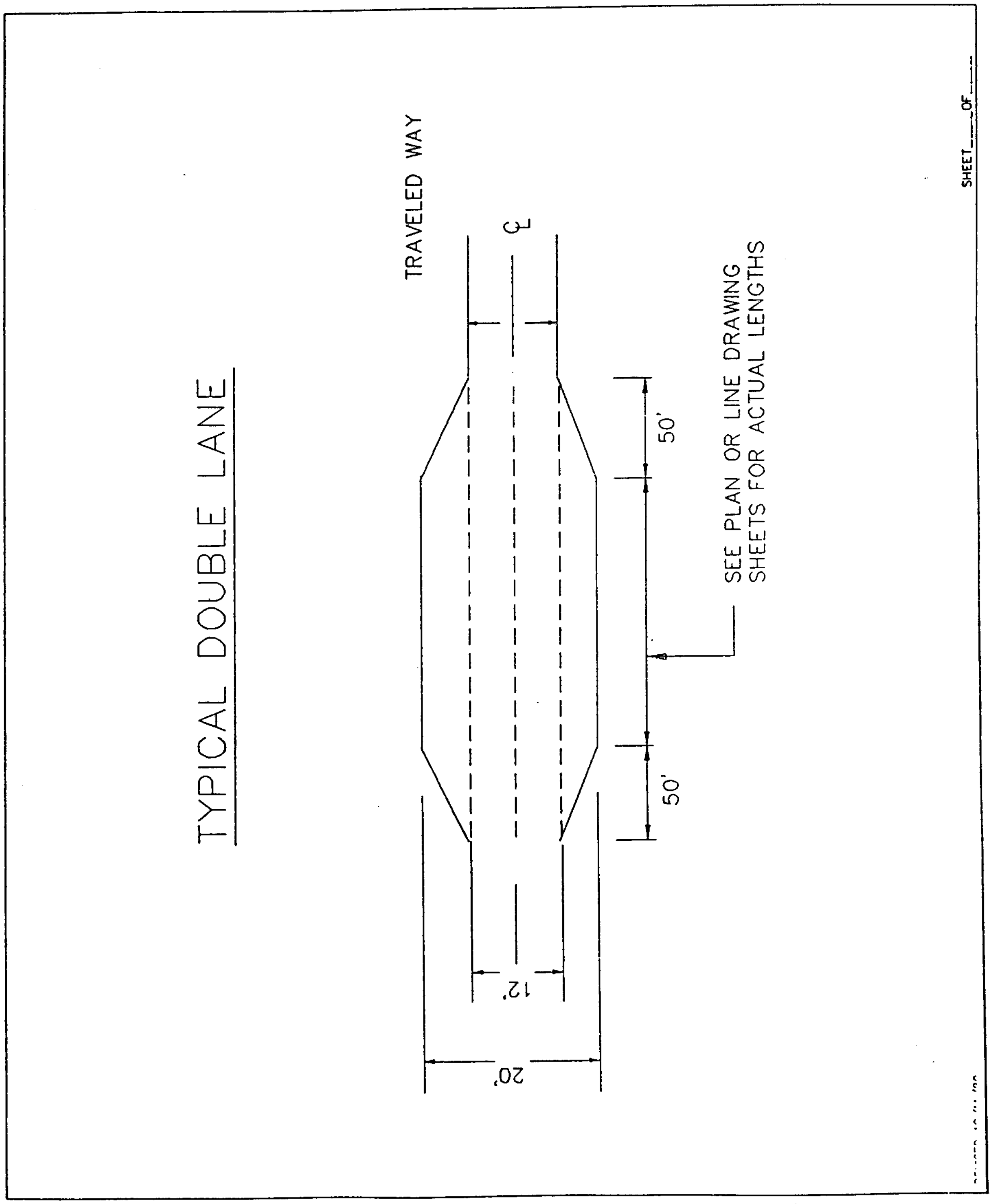
Economics is a basic factor in the determination and selection of alternative design standards. Develop standards using information that is applicable between the date of completion and the end of the planned use period.

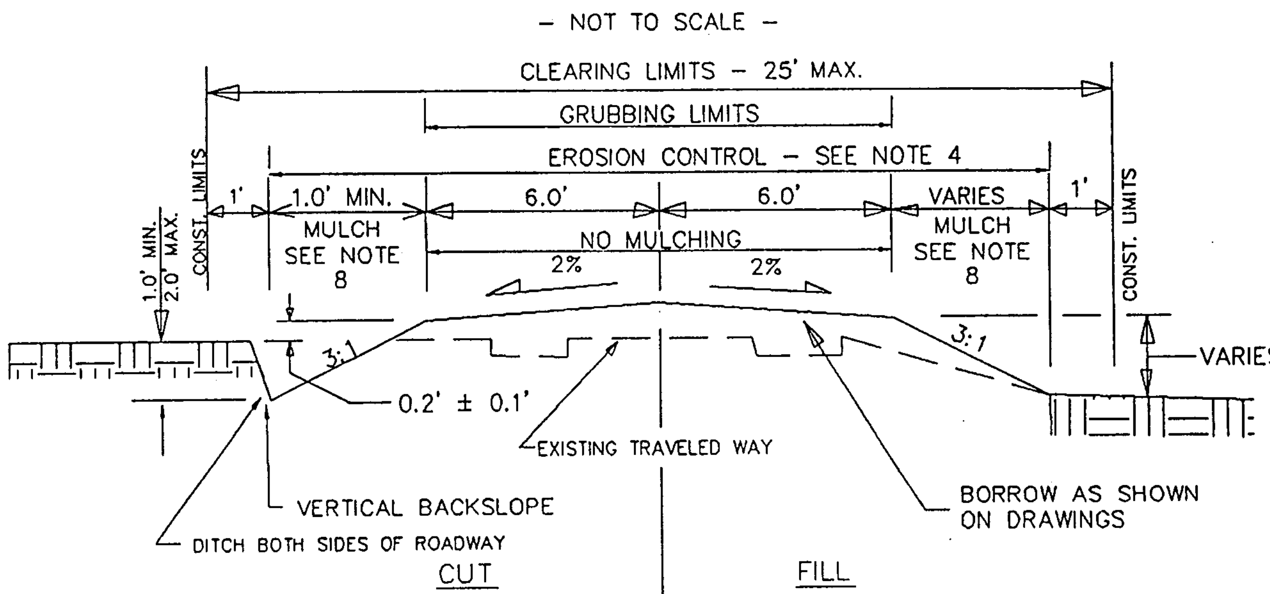
Design Forest development roads to serve the projected traffic requirements at the lowest cost for transportation (lowest total for construction plus maintenance and user costs) consistent with environmental protection and safety considerations.


TYPE "B" APPROACH DETAIL
-NOT TO SCALE-
SEE PLANS FOR CULVERT SIZE AND SETBACK
UNLESS OTHERWISE STATED ON PLANS
50' R
ROAD CENTERLINE
TRAVELED WAY
A
A
SETBACK
APPROACH STATION
75'
90° UNLESS OTHERWISE STATED ON PLANS
PLAN VIEW
TRAVELED WAY
CONSTR. AND/OR SURFACING LIMITS
75'
SETBACK
20'
SLOPE VARIES
1.5' MIN. COVER
PROFILE
CLEARING & GRUBBING LIMITS
SEEDING LIMITS
TRAVELED WAY
SEEDING LIMITS
10' D.L.
10' D.L.
2 %
2 %
CONSTRUCTION LIMITS
CONSTRUCTION LIMITS
1'
1'
2' MAX
2' MIN
3:1
3:1
SECTION "A"-"A"
SHEET____OF____


TYPE "A" APPROACH DETAIL
-NOT TO SCALE-
UNLESS OTHERWISE STATED ON PLANS
50' R.
ROAD CENTERLINE
TRAVELED WAY
APPROACH STATION
90° UNLESS OTHERWISE STATED ON PLANS
75'
A
A
PLAN VIEW
TRAVELED WAY
CONSTR. AND/OR SURFACING LIMITS
75'
SLOPE VARIES
PROFILE
CONSTRUCTION LIMITS
CLEARING & GRUBBING LIMITS
SEEDING LIMITS
TRAVELED WAY
SEEDING LIMITS
6' S.L.
10' D.L.
6' S.L.
10' D.L.
2 %
2 %
1'
1'
2' MAX.
2' MIN.
3:1
4:1
SEE TYPICAL SECTION FOR SURFACING
SECTION "A"-"A"
SHEET____OF____


TYPE "C" APPROACH DETAIL
-NOT TO SCALE-
A
A
℄
50' R.
UNLESS OTHERWISE STATED ON PLANS
ROAD CENTERLINE
TRAVELED WAY
APPROACH STATION
90° UNLESS OTHERWISE STATED ON PLANS
75'
PLAN VIEW
TRAVELED WAY
CONSTR. AND/OR SURFACING LIMITS
75'
35'
25'
FLOW LINE
4% MAX.
4% MAX.
10'
10'
℄
6" LIMEROCK
WOVEN FABRIC
12" LOOSE (±2") LIMEROCK(GRANULAR) FILTER BLANKET, MACHINE PLACED
PROFILE
NOTES:
SEE NOTES FOR LIMEROCK DIPS
CLEARING & GRUBBING LIMITS
SEEDING LIMITS
TRAVELED WAY
SEEDING LIMITS
CONSTRUCTION LIMITS
CONSTRUCTION LIMITS
6'
6'
2%
2%
1'
1'
SECTION "A"-"A"
SHEET____OF____


TYPICAL DOUBLE LANE
TRAVELED WAY
℄
SEE PLAN OR LINE DRAWING
SHEETS FOR ACTUAL LENGTHS
50'
50'
12'
20'
SHEET____OF____



TYPICAL SECTION

NOTES:

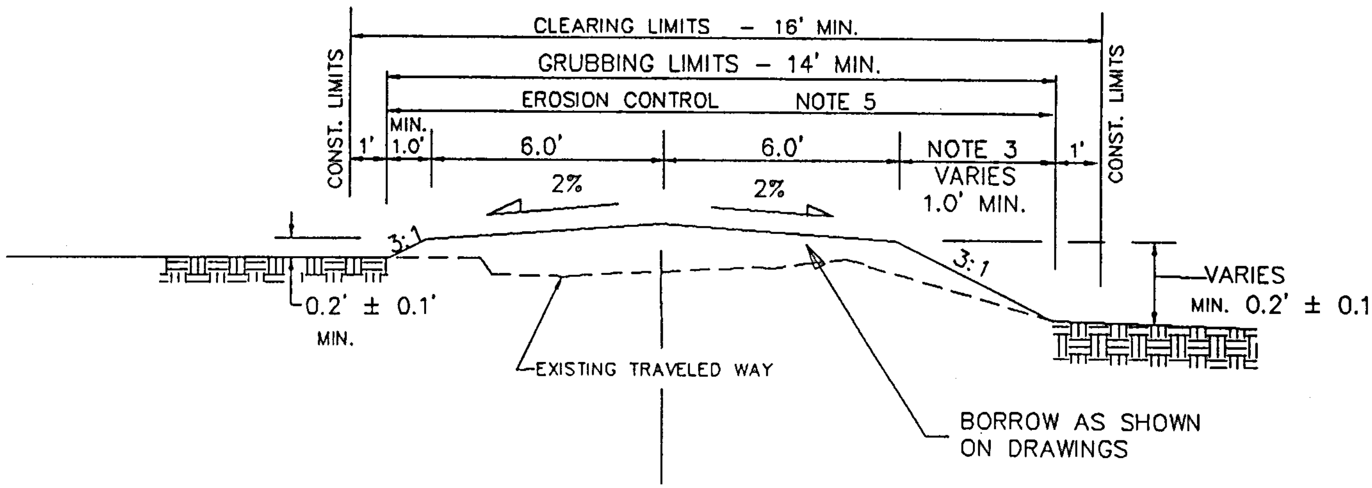
1. Excavation shall be completed prior to placement of borrow.
2. Finished roadbed shall be compacted by operating construction and hauling equipment over the entire width.
3. Ditch depth shall be varied to establish desired elevation (0.2' + 0.1') above natural ground.
4. Erosion Control shall consist of Seeding, Mulching, Fertilizing, and Lime.
5. Borrow shall be at or below optimum moisture at time of placement unless otherwise approved by Project Engineer.
6. Where no ditching or borrow is required, Crown or outslope as staked by Engineer to insure proper drainage.
7. Areas within clearing and grubbing limits that do not require work have not been included in design quantities for payment.
8. Mulch all cut slopes. Fill slopes shall be mulched when slope length exceeds 3'.

REVISED 8/23/89

SHEET____OF____

TYPICAL ROADWAY SECTION

– NOT TO SCALE –



TYPICAL SECTION

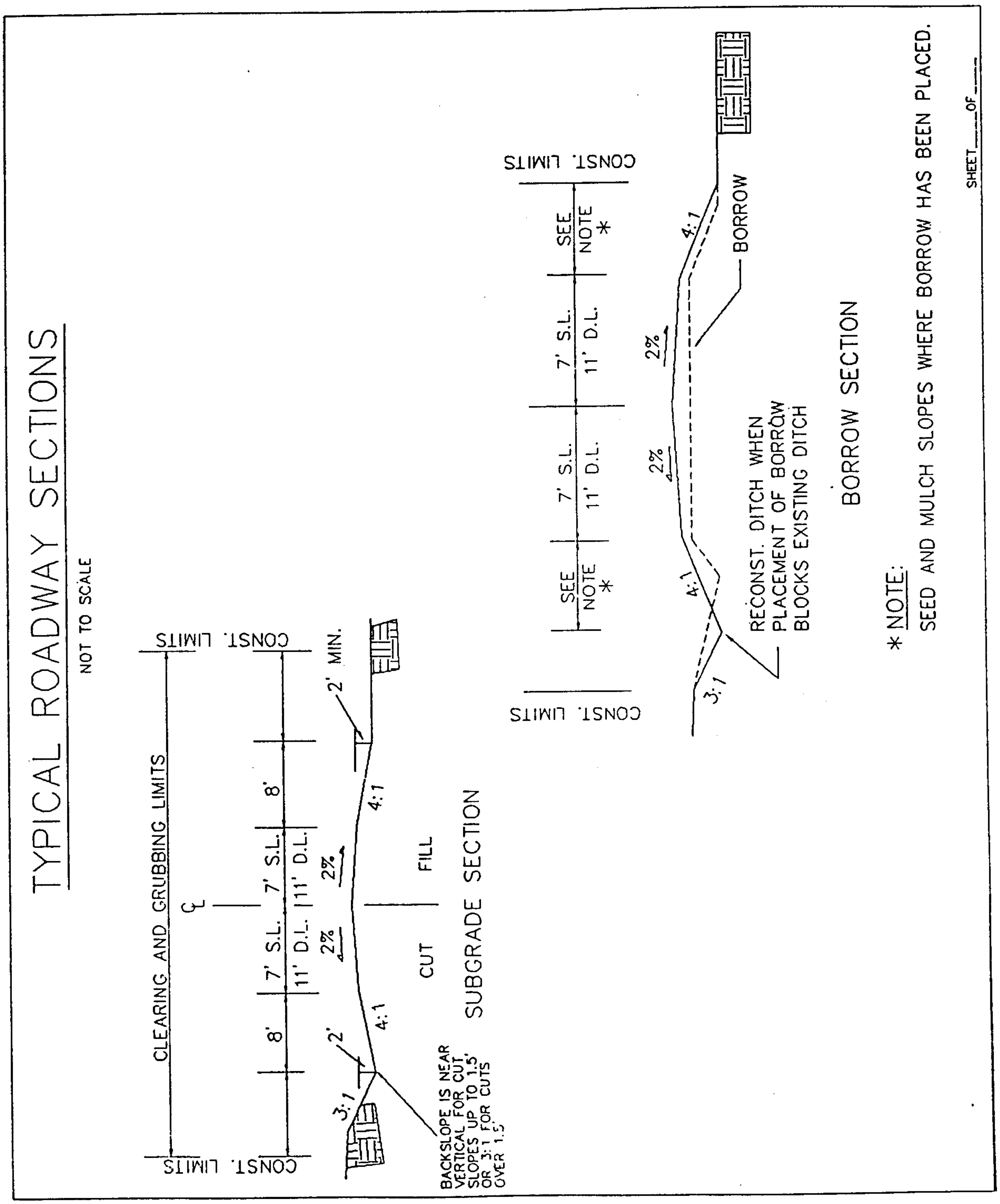
NOTES:

1. Travelway shall be shaped prior to placement of borrow.
2. Finished roadbed shall be compacted by operating construction and hauling equipment over the entire width.
3. Borrow shall be at or below optimum moisture at the time of placement unless otherwise approved by the Project Engineer.
4. Mulch slopes when slope length exceed 3'.
5. Areas within clearing and grubbing limits that do not require work have not been included in design quantities for payment.
6. Erosion Control shall consist of Seeding, Mulching, and Fertilizing.

Construction Tolerance Class I.

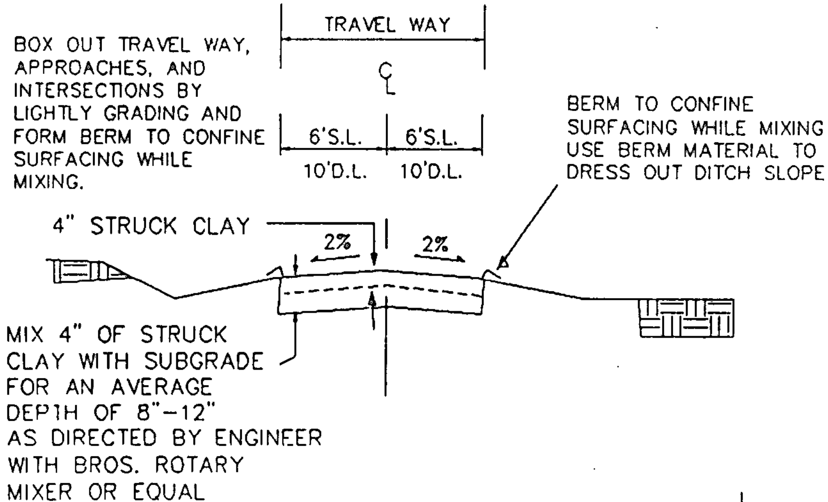
REVISED 10/11/89

SHEET____OF____


TYPICAL ROADWAY SECTIONS
NOT TO SCALE
CLEARING AND GRUBBING LIMITS
CONST. LIMITS
CONST. LIMITS
8'
7' S.L.
11' D.L.
7' S.L.
11' D.L.
8'
2%
2%
2'
2' MIN.
3:1
4:1
4:1
CUT
FILL
BACKSLOPE IS NEAR VERTICAL FOR CUT SLOPES UP TO 1.5' OR 3:1 FOR CUTS OVER 1.5'
SUBGRADE SECTION
CONST. LIMITS
CONST. LIMITS
SEE NOTE *
7' S.L.
11' D.L.
7' S.L.
11' D.L.
SEE NOTE *
2%
2%
3:1
4:1
4:1
BORROW
RECONST. DITCH WHEN PLACEMENT OF BORROW BLOCKS EXISTING DITCH
BORROW SECTION
* NOTE:
SEED AND MULCH SLOPES WHERE BORROW HAS BEEN PLACED.
SHEET____OF____

TYPICAL ROADWAY SECTIONS

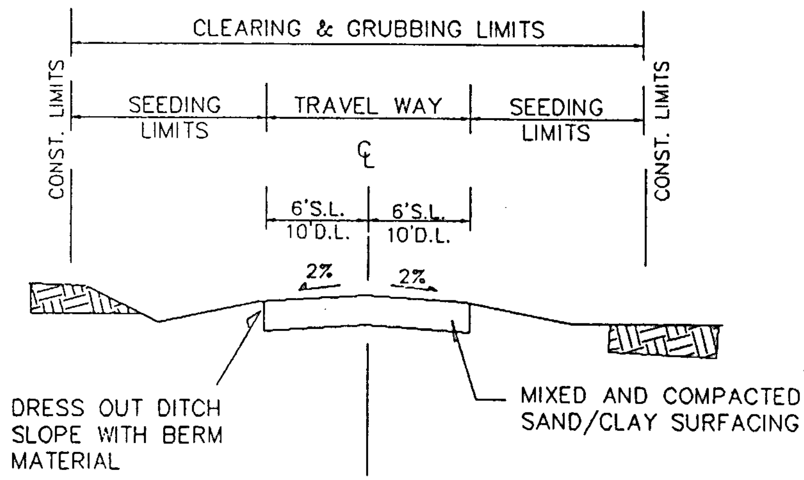
NOT TO SCALE



SURFACING SECTION

NOTES:

1. LIMEROCK SHALL MEET CURRENT FLORIDA DEPARTMENT OF TRANSPORTATION SPECIFICATION SECTION 911 – LIMEROCK FOR BASE AND STABILIZATION.
2. GRADATION AND SIZE REQUIREMENTS SHALL MEET THE REQUIREMENTS FOR LIMEROCK BASE.
3. CERTIFICATION OF LIMEROCK QUALITY SHALL BE FURNISHED BY THE SUPPLIER PRIOR TO PLACEMENT OF LIMEROCK.



FINISH SECTION

SHEET____OF____

Roadway Drainage

Drainage design is one of the most important elements in road design. Use the most economical control measure designed to meet resource and road management objectives and constraints. The economic considerations shall include construction and maintenance costs.

The results of poor or improper drainage design are often dramatic and destructive. The natural equilibrium of slope hydrology is easily upset by the introduction of artificial systems. Other specialists can help to establish the most appropriate onsite water handling objectives. Inadequate drainage may result in releasing or impounding water on Eglin or private land where it is undesirable or damaging.

Proper road location can minimize the need for drainage structures. However, it is essential to use adequate drainage for a stable road.

All drainage can be classified as one of two types—surface or subsurface. The classification depends on whether the water is on or below the surface of the ground at the point where it is first intercepted or collected for disposal.

For a proper drainage system, use the best combination of various design elements, such as ditches, culverts, drainage dips, crown, in slope or out slope, fords, subsurface drains, and bridges. As the basis for the drainage design, use the most economical system that meets the design criteria derived from land management objectives.

Surface drainage. Surface drainage provides for the interception, collection, and removal of water from the surface of roads and slope areas. This is important because water on the surface may interfere with traffic or cause erosion, and if allowed to infiltrate, may cause damage to the subgrade.

The design may need to allow for debris passage, mud flows, and water heavily laden with silt, sand, and gravel.

Review projects that might affect fish migration or passage with an appropriate specialist or resource manager to ensure that the design conforms to the resource management objectives.

Subsurface drainage. Subsurface drainage intercepts, collects, and removes groundwater that may flow into the base course and subgrade; lowers high water tables; and drains water pockets.

Water is present under the surface because of the infiltration of surface and groundwater. Water seeps down through unsealed surfaces and moves laterally along the top of impervious soil or rock layers. Ground water may pond above impervious strata to form a perched water table.

Properly designed and maintained surface drainage systems may reduce the need for special subsurface drainage structures.

Culverts

When checking for damage potential include an analysis of probable damage to the structure, the road, and the drainage upstream and downstream from the structure and consider the effects of possible debris loading.

Ditch relief culverts. Provide ditch relief culverts to periodically relieve the ditch line flow by piping water to the opposite side of the road where the flow can disperse away from the roadway. The spacing of ditch relief culverts depends on the road gradient, road surface and ditch soil types, runoff characteristics, and the effect of water concentrations on slopes below the road.

Low-volume road gradients are often steep because of economics and a desire to disturb the least amount of land. Ditch relief culverts installed in roads with steep grades, particularly in steep mountainous terrain with high intensity storms, have an increased potential for failure. Failure may result in increased ditch scour, extensive erosion of road surfacing, and mass failure of roadway fills.

Analyze alternatives of flatter versus steeper gradients, comparing the cost of construction versus the cost of road repair, maintenance, and damage to the adjacent resources.

Debris blockage causing culvert failure can lead to a domino effect. When one culvert fails, debris and water flow to the next culvert and may result in its failure, and so on. Therefore, include in the design provisions for protecting culverts from debris where a potential problem exists.

Drainage failures may also have a detrimental effect on land below the road. Siltation in streams and degradation of water quality may be increased and fish habitat damaged. Runoff concentration increases surface erosion, mass soil movement, and stream channel scour.

Ensuring proper cover lessens the change of damage to the culvert barrel and inlet end. To minimize damage, provide adequate cover for the design life of the culvert. This requires anticipating the amount of material that may be lost due to road use and erosion.

Skewing ditch relief culverts from a line perpendicular to the centerline of the road may improve flow characteristics, reduce siltation problems, and reduce the possibility of debris plugging the culvert inlet. Do not use skewing to increase the distance between ditch relief culverts. Skewing may increase the length of culvert necessary for the location. When determining the degree of skew, consider the following factors: (a) the additional cost caused by the additional culvert length, (b) proper dispersion of water below the road, and (c) improved flow characteristics through the pipe. Do not use skewing when water is flowing toward the culvert inlet from both directions, except to reach or fit a natural channel.

Provide for ditch relief culverts during design. Determine the location of the inlet of relief culverts to provide for design of inlet basins. The design of inlet basins should include adequate width for the culvert entrance and for any structure necessary to prevent erosion of the road bed and backslope. Design inlet basin backslopes at stable slope to minimize the possibility of culvert plugging from ravel or slumping. Where practical, provide a transition taper between the normal backslope and the inlet basin backslope. Inlet structures may consist of hand-laid rock headwalls, ditch dams, inlet basin liners, drop inlets, or other special structures designed for specific conditions at the site.

It is also possible to use culverts placed in natural drainages for ditch relief; however, consider the effect of possible sedimentation or increased flows on the natural drainage.

Designing culverts for later removal may be beneficial for intermittent-use roads that are to be closed for extended periods of time. Culverts designated for removal may be constructed from permanent materials or materials that wear out after their initial use. Base the decision of which type of material to include in the design on economics and risks of environmental damage.

In high-use recreation areas and other visually sensitive locations, consider reducing the visual impact of culverts by painting the ends with asphalt or other materials to reduce color contrast.

Wetland Crossings. It is important to design wetland crossings properly to protect the resources that are sensitive to unnatural fluctuations in water level. Marshy and swampy terrain may contain bodies of water with no discernible current, so designing culverts for roads crossing these locations requires some unique considerations.

Design wetland culverts with a nearly flat grade so that water can flow either way and maintain the natural water level on both sides. The culvert may be partially blocked by aquatic growth and installed with the flow line below the standing water level at its lowest elevation. Give special attention to selecting culvert materials that resist corrosion.

Ditches

When planning the geometric design of ditches, consider the resource objectives for soil, water, and visual quality, maintenance capabilities and associated costs, and construction costs. Ditch grades should be no less than 0.5 percent to provide positive drainage and to avoid siltation. The following lists the usual types of ditches and describes their use:

Drainage ditch. Ditches transport water that leaves the road surface or cut slope to the nearest ditch relief culvert or outlet ditch and drain the road-bed. The ditch is constructed between the traveled way and the adjacent terrain.

In some cases, vehicles may use the drainage ditch to avoid collision with other vehicles. The inslope (foreslope) should not be steeper than 3:1. Experience indicates that vehicles can drive safely into a drainage ditch at less than 20 miles per hour if the inslope is 3:1 or flatter. Consider providing clearance for larger vehicles by properly dimensioning ditches.

Trap ditch. Where necessary, design trap ditches to catch and hold slough and to hold snow. Because it is a form of drainage ditch, the trap ditch can perform all the functions of a drainage ditch.

Intercepting ditch. Where necessary, use an intercepting ditch to protect the roadbed and roadway cut and fill slopes. On the cut side, locate the ditch above the catch point of the cut slope to intercept runoff and channel it away.

On the fill side, the ditch intercepts water traveling along the fill and prevents erosion of the toe of the fill. The location of this type of ditch should be along the toe of fills where the ground is fairly flat and where cut slopes daylight into fill slopes to prevent water leaving outlet ditches from traveling directly against the fill slope.

Outlet ditch. Outlet ditches carry water away from the road to prevent the road subgrade from being saturated or eroded. This ditch is normally used in fairly flat ground when the topography does not allow the water to run away from the road. Locate the ditch at the lower end of a culvert or drain dip, or at the point where a roadside ditch daylights out into natural ground.

Drainage dips

Drainage dips intercept and remove surface water from the traveled way and shoulders before the combination of water volume and velocity begins to displace the surface materials. Do not confuse drainage dips with water bars, which are normally deeper and are primarily for drainage and erosion protection of closed or blocked roads.

Drainage dips are useful for low-volume, low-speed roads where there may be extended periods of nonuse. When properly constructed, they can provide a relatively maintenance-free drainage structure.

Drainage dips may be beneficial in heavily debris-laden areas where culverts may plug and create erosion problems during periods of high runoff. They also are useful as a traffic control measure for reducing travel speeds.

The initial construction costs of a drainage dip may be cheaper than purchasing and installing a culvert pipe, constructing the roadside drainage ditch, and maintaining the culvert and ditch. However, unless the dip is properly designed and constructed, the total cost, including maintenance, may be more than if a culvert pipe had been installed.

The disadvantages of dips are low travel speeds, poor riding comfort, difficult blading of the traveled way, and possible adverse affects on water quality.

Road maintenance costs may increase because of discontinuity of the blading operation. Avoid constructing drainage dips on road grades greater than 10 percent because of increased vehicle operation difficulties, added erosion, and resultant maintenance problems. On road grades in excess of 10 percent, consider other surface drainage facilities, such as open-top drains.

Dips should discharge runoff in small amounts before runoff can significantly accumulate. Dips skewed from the perpendicular to the road centerline may drain and self-maintain better than dips that are not skewed. However, an unskewed dip normally results in better driving characteristics. The downstream barrier of the dip should not create a "hump" in the grade. Taper the downhill slope to blend with the road gradient.

It may be desirable to stabilize the crest and trough portions of the dip with aggregates or in-place soil treatments to reduce deformation and to maintain stability.

Where tractor-trailer vehicles are the design vehicles, use the following guidelines when designing dips on grades greater than 8 percent:

a. Do not locate drainage dips within the confines of curves that have radii of less than 100 ft.

b. Maintain constant inslope or outslope throughout the length of the drainage dip to avoid the racking of truck frames. Do not deepen the outlet of the dip.

c. Construct transitions at least 60 ft long in both directions from the low point and the crest to avoid abrupt changes in grade.

Inslope, outslope, and crown

Roadway surfaces are normally crowned or sloped to remove surface water from the wearing surface. The amount of crown or slope varies with the type of surface, and is generally less for impervious surfaces, such as asphalt, and greater for relatively pervious surfaces, such as gravel or native soils. If the cross slope is too flat, water remains on the road surface for a longer period of time and may penetrate into the base course and subgrade. A large buildup of moisture below the surface may cause instability and severely reduce the road's load-carrying capabilities.

Roads may be insloped (graded toward the cut) or outsloped (graded toward the embankment) depending on the resistance of the soil to erosion and based on the benefits of dispersing water gradually (outslope) or concentrating it into a specific location (inslope). Where the soil is unstable or subject to

major erosion, the design should provide for inslope grading. It may be necessary to stabilize ditches or the toe of the cut slope on insloped or crowned roads to reduce erosion. Out-sloping or insloping of the roadway surface for removal of water becomes less effective as grade increases.

The decision to inslope or outslope depends, in part, on the natural slope hydrology; that is, how the undisturbed slope handles water. Convex topography tends to disperse water and concave topography tends to concentrate water into defined drainages. Outsloping roads complement convex topography, while insloping roads with well-placed cross drainage tend to work best with concave topography.

It is usually unnecessary to use ditches with outsloping roads, and they may not be necessary with insloping. Make this determination based on the erosive characteristics of the soil, precipitation, runoff ratios, gradients, and the length of run before the water can be removed.

Outsloping can be hazardous when roads become slippery. The cross grades of roads are usually 4 percent or less because slow moving vehicles, such as logging trucks, have a tendency to slip sideways when they lose their momentum on slippery surfaces. This is particularly troublesome on horizontal curves.

Subdrainage systems

The design should provide subdrainage to remove water from the subgrade or pavement structure, to improve stability and load bearing capacity, to decrease the danger of frost action, or to reduce a safety hazard caused by freezing water on the traveled way.

Design subsurface drainage systems to accomplish the following: (1) intercept groundwater that cannot be intercepted by side ditches before entering the travelway, (2) reduce the hydrostatic pressure behind structures, (3) release ground-water into suitable channels without causing erosion or silting, and (4) last as long as the travelway or structure.

Because each site is different, conduct a field investigation to determine the best solution. The field investigation may include:

a. Reviewing available soil and geological studies or gathering new data.

b. Making borings or digging test holes to locate groundwater.

c. Inspecting natural lakes and slopes in the area and studying the natural drainage patterns.

d. Measuring discharge when possible.

e. Testing slope stability.

Perforated pipe drains are a common solution, but they do not function properly unless some method is used to prevent the holes from plugging. The following are several alternatives that prevent plugging, depending upon the characteristics of the soil:

a. Use a prefabricated drain, which consists of a geotextile covering one or both sides of a drain core material. The core provides open channels for water flow.

b. Surround the pipe with an open-graded aggregate material, which, in turn, is surrounded by a geotextile. The use of fabric material eliminates the need for an inverted filter consisting of various-sized gravel and sand layers.

c. Use a graded aggregate filter. (Use of this filter has diminished with the advent of geotextiles.)

Other types of subsurface systems include the following:

a. *Drilled drains*. For this system, place perforated pipes in holes drilled into cut or fill slopes to intercept the groundwater flow.

b. *French drains*. This system is identical to the pipe under-drain system, except a perforated pipe is not used. Use a large rock for the drainage path.

c. *Engineered drainage systems*. This type of system usually consists of a porous, chemically inert medium covered on one or both faces with a geotextile material. Place the system directly in a trench or against a structure and back-fill it with excavated material. This system can eliminate the need for special backfill necessary with the pipe under-drain and French drain systems.

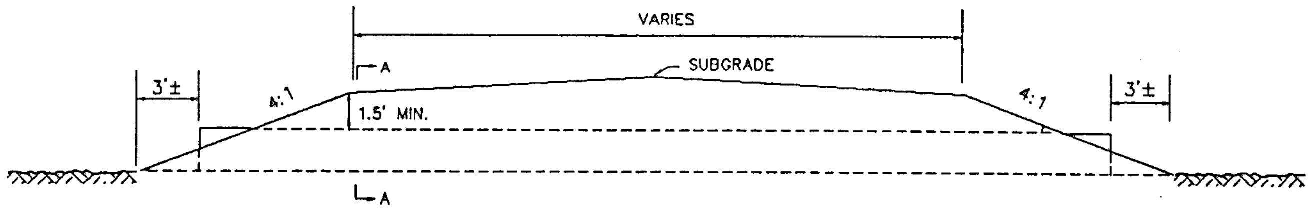
Select a system that best meets the structural requirements and the corrosive conditions of the soil and water.

Because of the complexity of soils in many areas, it is advisable to consult materials specialists about the use and performance of the various types of geotextiles and graded aggregate filters. See section 4.74 for a further discussion of geotextiles.

Subdrainage systems may effectively reduce final road costs by decreasing the depth of base rock needed and reducing subgrade widths. This, in turn, results in less clearing and excavation. Maintenance savings also may be possible as the result of a more stable subgrade.

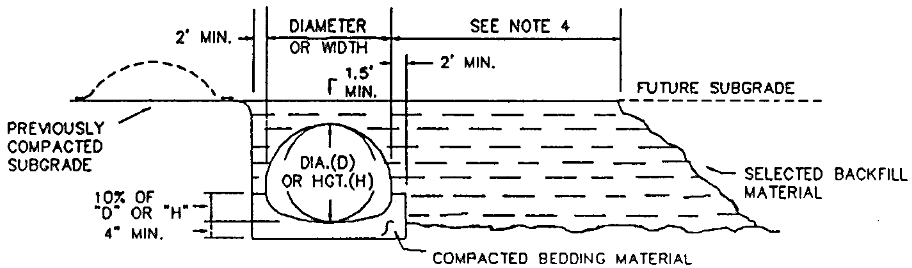
The solutions to subdrainage problems can be expensive. Consider as alternatives road management techniques, such as reducing traffic loads or removing traffic until a subgrade dries out.

TYPICAL SECTIONS—CULVERT INSTALLATION



NOTE: CLEAN AROUND ENDS OF PIPE TO PROVIDE UNOBSTRUCTED FLOW MIN. 3 PIPE DIAMETERS OR SPANS IN EACH DIRECTION.

PROFILE



SECTION A–A

CULVERT SCHEDULE

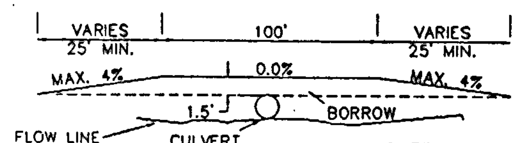
Bituminous Coated Corrugated Steel Pipe			
SIZE	21" x 15"	28" x 20"	35" x 24"
THICKNESS	0.064"	0.064"	0.079"
COATING	"A"	"A"	"A"
FDR STATION			
PROJECT TOTAL			

NOTES:

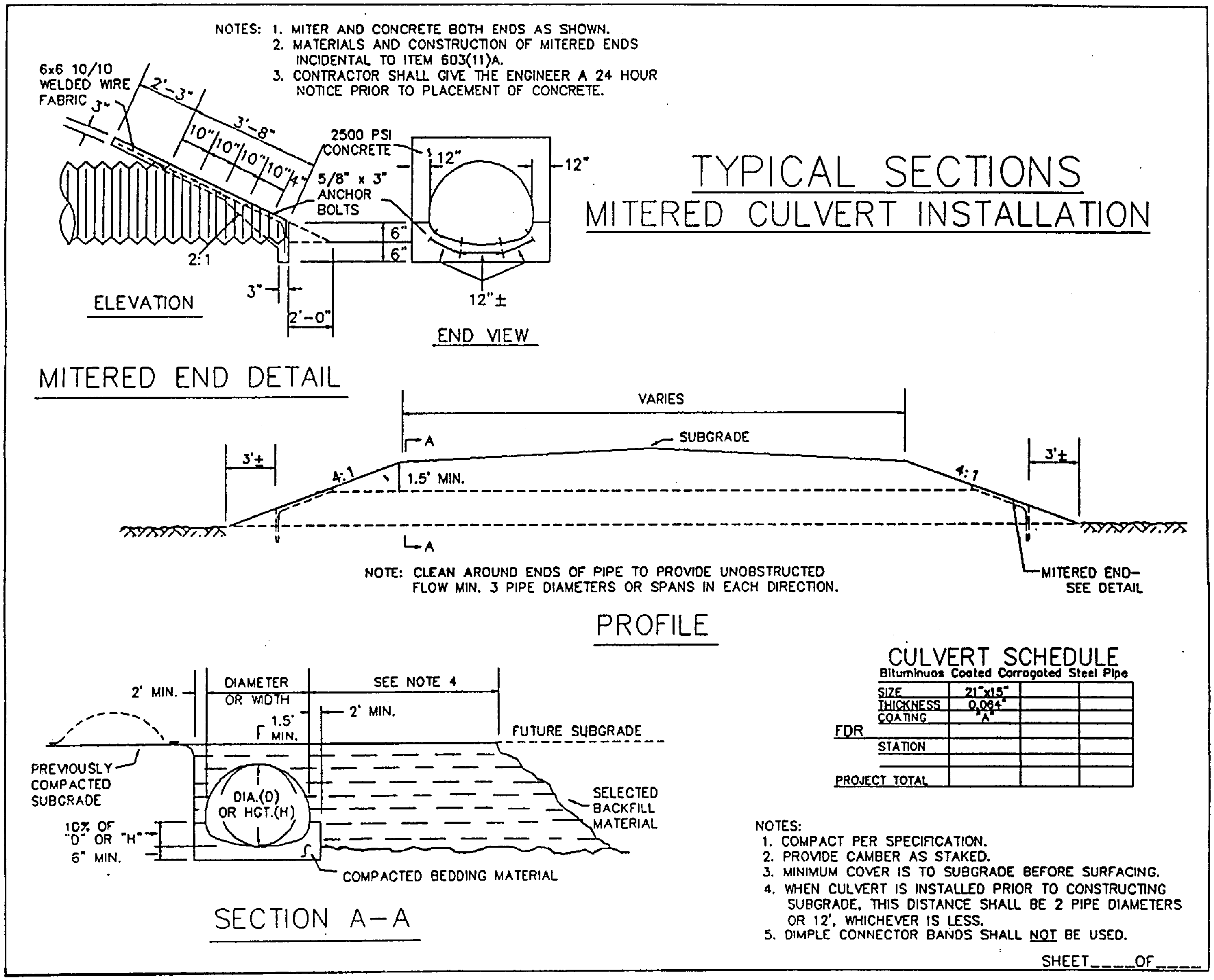
1. COMPACT PER SPECIFICATION.
2. PROVIDE CAMBER AS STAKED.
3. MINIMUM COVER IS TO SUBGRADE BEFORE SURFACING.
4. MINIMUM SPACING BETWEEN CULVERTS, EDGE TO EDGE, IS 36" OR 1/2 DIA. OR 1/2 OF SPAN, WHICHEVER IS LARGER, UNLESS OTHERWISE STATED IN THE PLANS.
5. WHEN CULVERT IS INSTALLED PRIOR TO CONSTRUCTING SUBGRADE, THIS DISTANCE SHALL BE 2 PIPE DIAMETERS OR 12', WHICHEVER IS LESS.
6. DIMPLE CONNECTOR BANDS SHALL NOT BE USED.
7. PIPES OVER 36" DIA. SHALL BE SUPPLIED WITH LIFTING RINGS.
8. HELICAL PIPE SHALL HAVE RE-ROLLED ENDS.

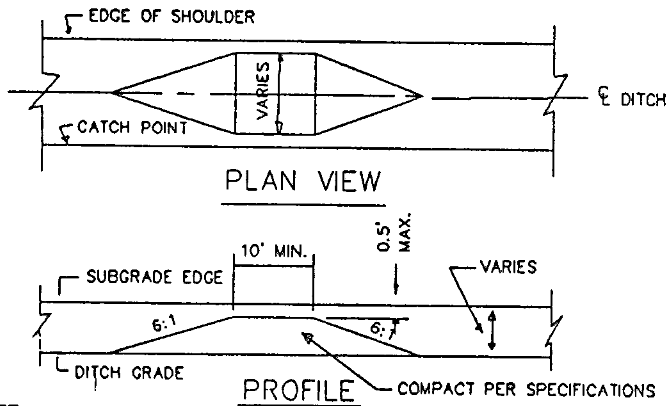
TYPICAL CULVERT INSTALLATION

ROAD PROFILE
AT CULVERT LOCATION



SHEET____OF____

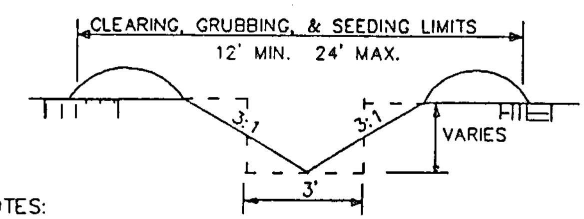

TYPICAL SECTIONS
MITERED CULVERT INSTALLATION
NOTES: 1. MITER AND CONCRETE BOTH ENDS AS SHOWN.
2. MATERIALS AND CONSTRUCTION OF MITERED ENDS INCIDENTAL TO ITEM 603(11)A.
3. CONTRACTOR SHALL GIVE THE ENGINEER A 24 HOUR NOTICE PRIOR TO PLACEMENT OF CONCRETE.
6x6 10/10 WELDED WIRE FABRIC
3"
2'-3"
3'-8"
10"
10"
10"
10"
4"
2500 PSI CONCRETE
5/8" x 3" ANCHOR BOLTS
2:1
3"
2'-0"
6"
6"
12"
12"
12"±
ELEVATION
END VIEW
MITERED END DETAIL
VARIES
SUBGRADE
A
A
3'±
3'±
4:1
4:1
1.5' MIN.
NOTE: CLEAN AROUND ENDS OF PIPE TO PROVIDE UNOBSTRUCTED FLOW MIN. 3 PIPE DIAMETERS OR SPANS IN EACH DIRECTION.
MITERED END- SEE DETAIL
PROFILE
2' MIN.
DIAMETER OR WIDTH
SEE NOTE 4
2' MIN.
1.5' MIN.
FUTURE SUBGRADE
PREVIOUSLY COMPACTED SUBGRADE
DIA.(D) OR HGT.(H)
SELECTED BACKFILL MATERIAL
10% OF "D" OR "H" 6" MIN.
COMPACTED BEDDING MATERIAL
SECTION A-A
CULVERT SCHEDULE
Bituminuos Coated Corrogated Steel Pipe
SIZE 21"x15"
THICKNESS 0.064"
COATING "A"
FDR
STATION
PROJECT TOTAL
NOTES:
1. COMPACT PER SPECIFICATION.
2. PROVIDE CAMBER AS STAKED.
3. MINIMUM COVER IS TO SUBGRADE BEFORE SURFACING.
4. WHEN CULVERT IS INSTALLED PRIOR TO CONSTRUCTING SUBGRADE, THIS DISTANCE SHALL BE 2 PIPE DIAMETERS OR 12', WHICHEVER IS LESS.
5. DIMPLE CONNECTOR BANDS SHALL NOT BE USED.
SHEET____OF____



NOTE:

1. DITCH BLOCK CONSTRUCTION CONSIDERED INCIDENTAL ITEM TO ITEM 203(07).

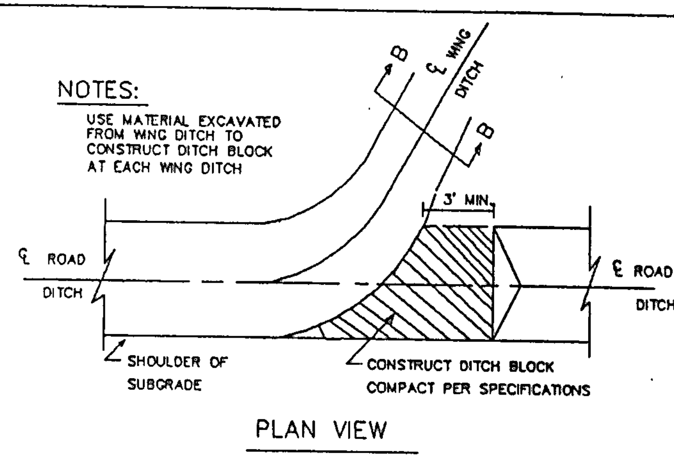
TYPICAL DITCH BLOCK

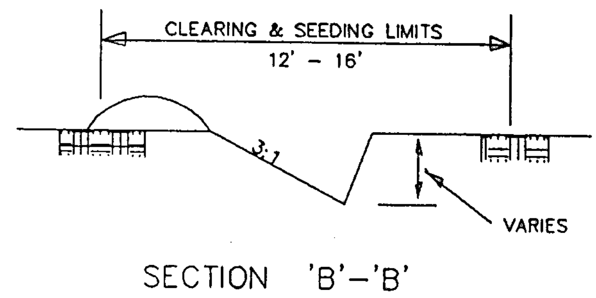


NOTES:

1. DITCH LOCATIONS SHOWN ON PLAN OR LINE DRAWING SHEETS TO BE STAKED BY ENGINEER WITH SAME DEPTH AS SIDE DITCH.
2. LEAD-OFF DITCH CONSTRUCTION CONSIDERED INCIDENTAL TO PAY ITEM 299(01).
3. DASHED LINE INDICATES DITCH CONSTRUCTED WITH A BACKHOE
4. CONSTRUCT L.O.D. TO DRAIN TO DAYLIGHT OR 100' MAXIMUM.

TYPICAL LEAD-OFF DITCH





NOTES:

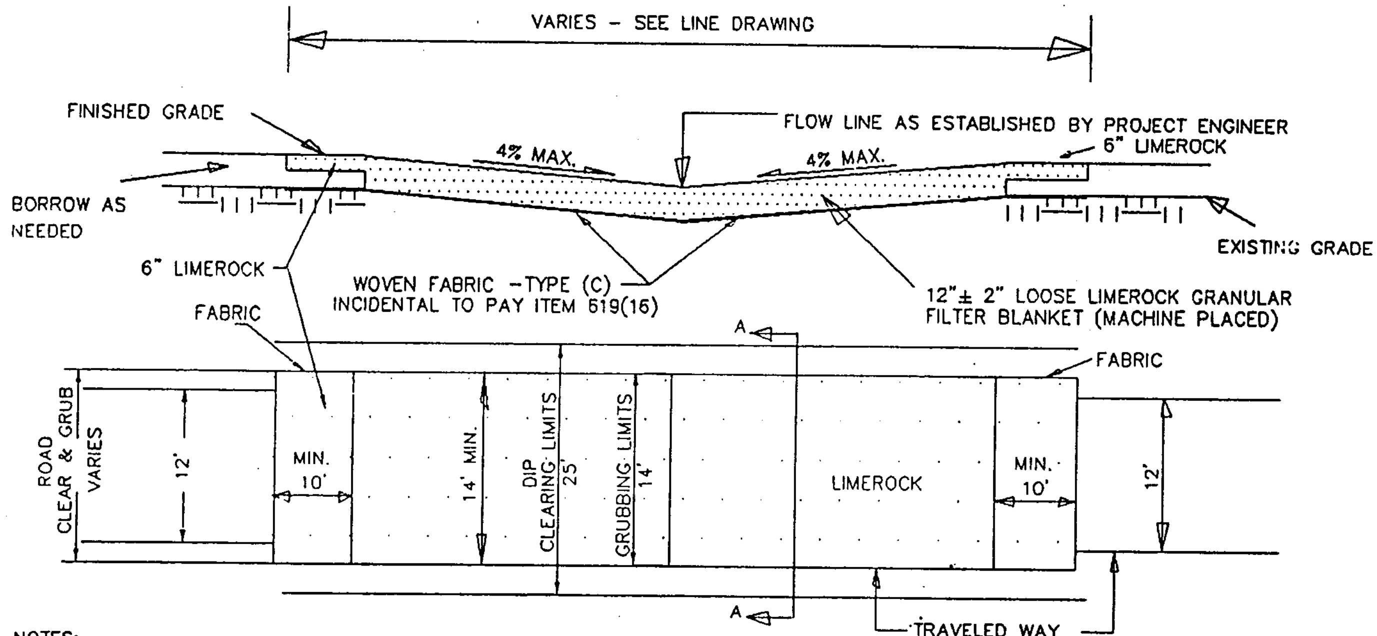
1. WING DITCH SLOPE SHALL BE EQUAL TO OR LESS THAN ROAD GRADE, WITH NOT MORE THAN 2% DIFFERENCE
2. CONSTRUCT WING DITCHES TO DRAIN TO DAYLIGHT OR 100' MAXIMUM.
3. WING DITCH CONSTRUCTION CONSIDERED INCIDENTAL TO PAY ITEM 203 (07).

WING DITCH DETAILS

SHEET___OF___

TYPICAL LIMEROCK DIP DETAIL

(NOT TO SCALE)

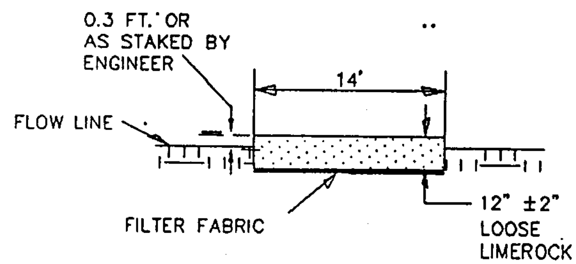


NOTES:

1. LIMEROCK SHALL BE TRUCK DUMPED AND MACHINE SPREAD OVER THE FABRIC FOLLOWING PLACEMENT OF FABRIC.
2. COMPACTION SHALL BE ACCOMPLISHED BY SPREADING EQUIPMENT.
3. FABRIC SHALL CONFORM TO SECTION 720 (TYPE C).
4. MINIMUM FABRIC OVERLAP SHALL BE 6' ON EACH EDGE. ROCK SHALL BE PLACED ON LAP PRIOR TO PLACING ROCK ON SINGLE LAYERS OF FABRIC TO PREVENT LATERAL MOVEMENT.
5. ALL MATERIALS TO BE PROVIDED BY THE CONTRACTOR.
6. UNLESS OTHERWISE APPROVED BY ENGINEER LIMEROCK SHALL MEET THE FOLLOWING GRADATION AS PER SPS FL. 619.1

GRADATION:

SIEVE	% PASSING
6"	98 - 100
4"	40 - 55
1/2"	0 - 5
L A ABRASION	37 - 40



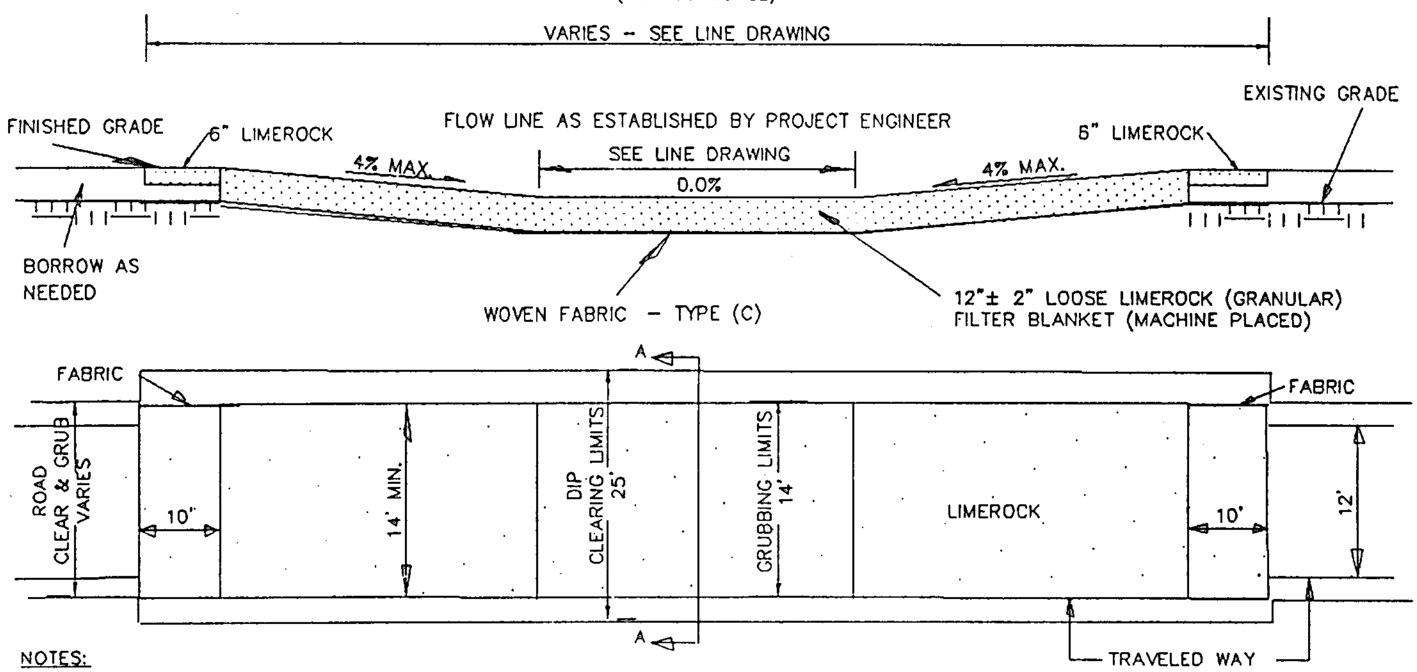
SECTION A - A

REVISED 7/3/89

SHEET____OF____

TYPICAL LIMEROCK DIP (FLAT BOTTOM) DETAIL.

(NOT TO SCALE)

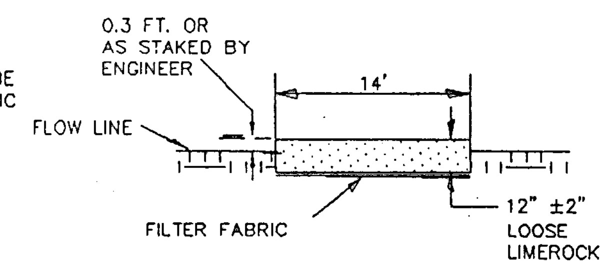


NOTES:

1. LIMEROCK SHALL BE TRUCK DUMPED AND MACHINE SPREAD OVER THE FABRIC FOLLOWING PLACEMENT OF FABRIC.
2. COMPACTION SHALL BE ACCOMPLISHED BY SPREADING EQUIPMENT.
3. FABRIC SHALL CONFORM TO SECTION 720 (TYPE C).
4. MINIMUM FABRIC OVERLAP SHALL BE 6' ON EACH EDGE. ROCK SHALL BE PLACED ON LAP PRIOR TO PLACING ROCK ON SINGLE LAYERS OF FABRIC TO PREVENT LATERAL MOVEMENT.
5. ALL MATERIALS TO BE PROVIDED BY THE CONTRACTOR.
6. UNLESS OTHERWISE APPROVED BY ENGINEER LIMEROCK SHALL MEET THE FOLLOWING GRADATION AS PER SPS FL. 619.1

GRADATION:

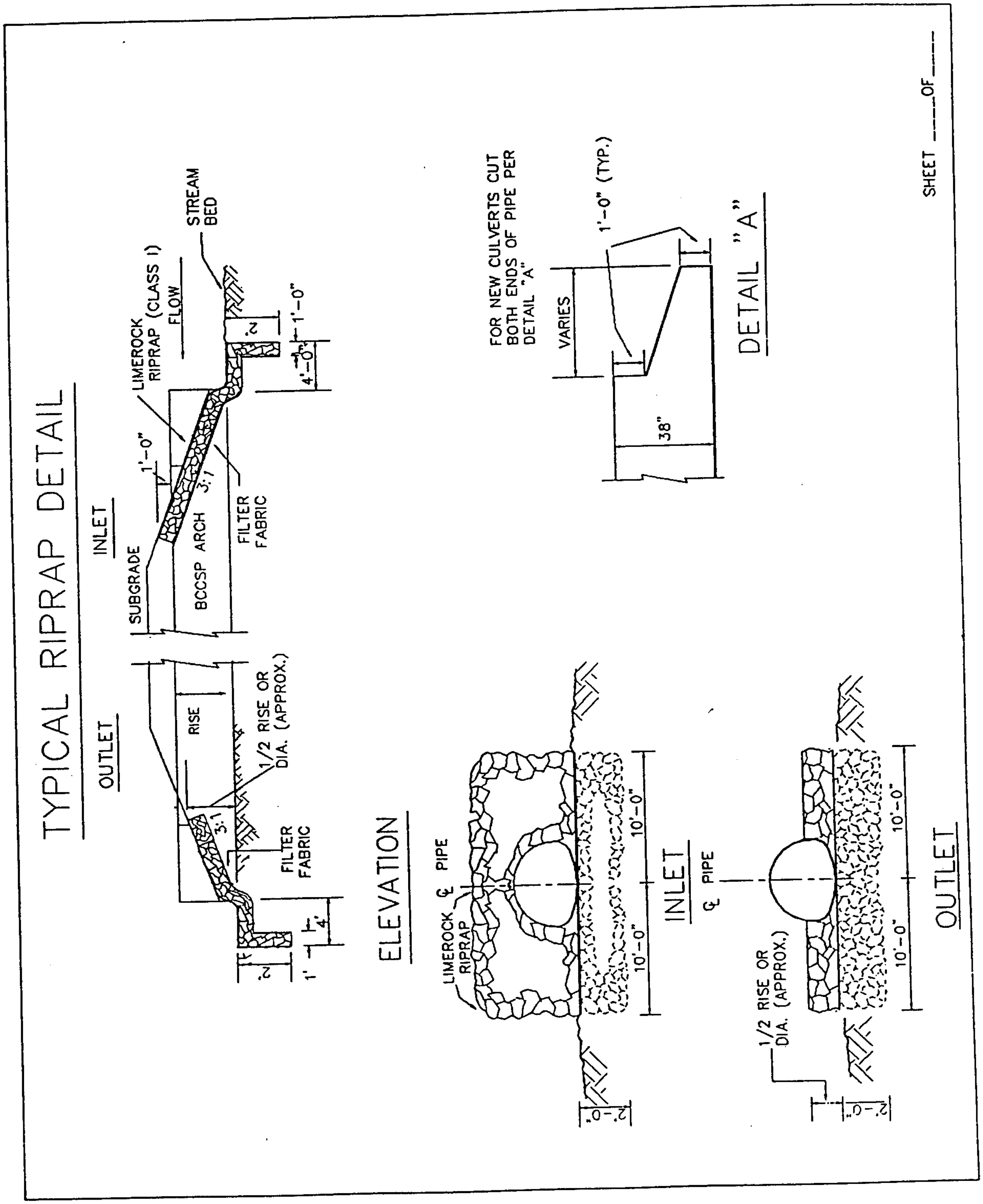
SIEVE	% PASSING
6"	98 - 100
4"	40 - 55
1/2"	0 - 5
L A ABRASION	37 - 40



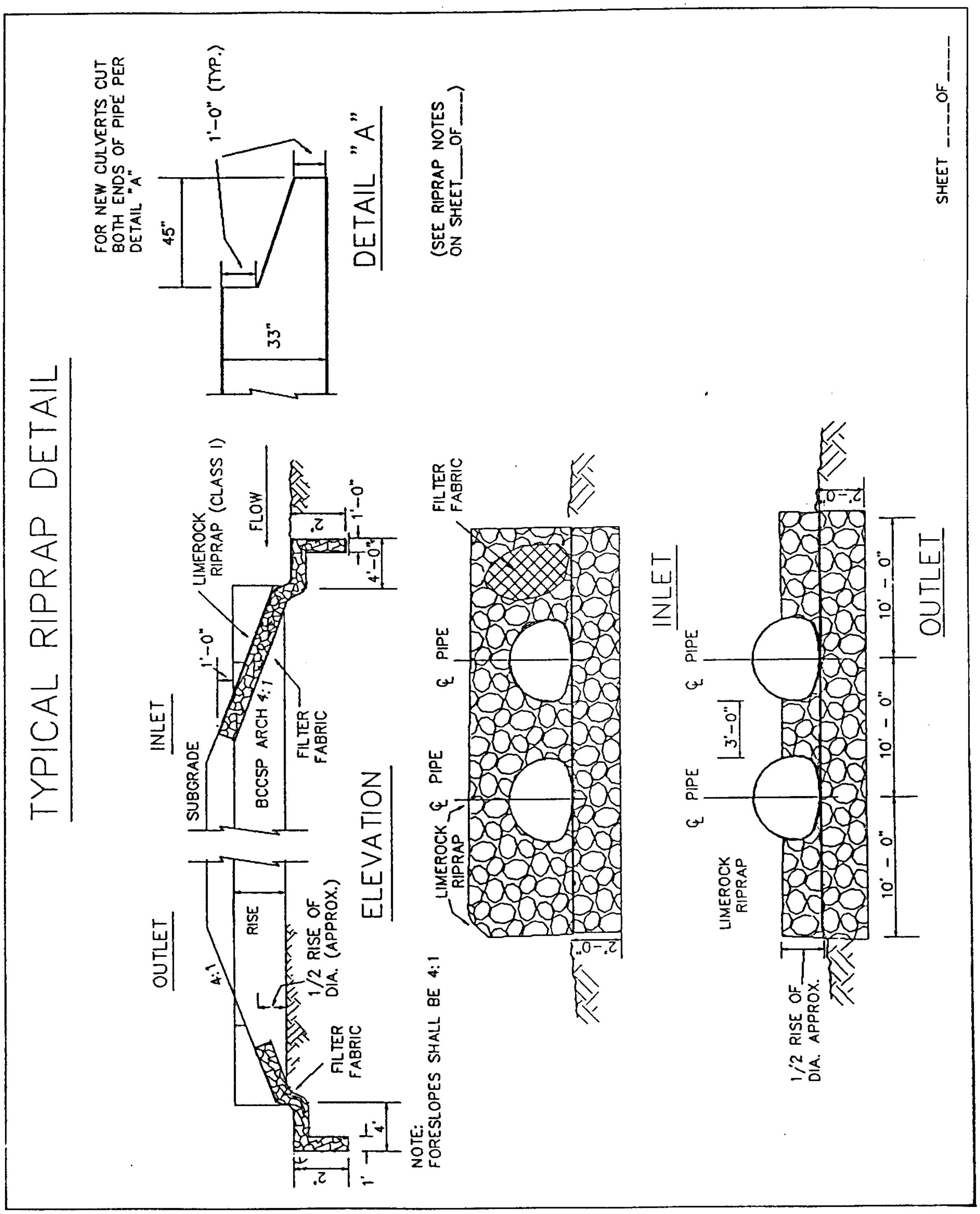
SECTION A – A

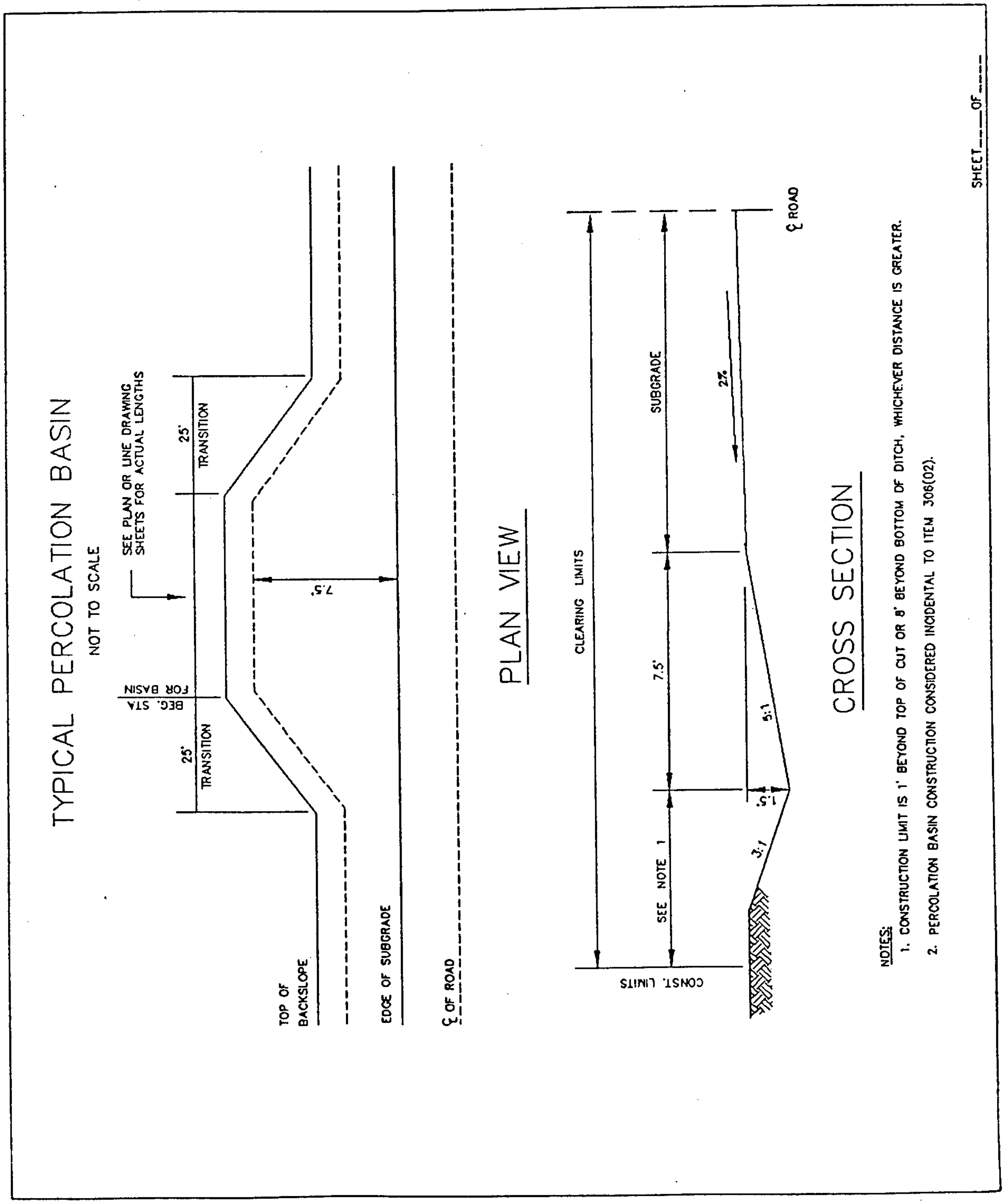
REVISED 7/3/89

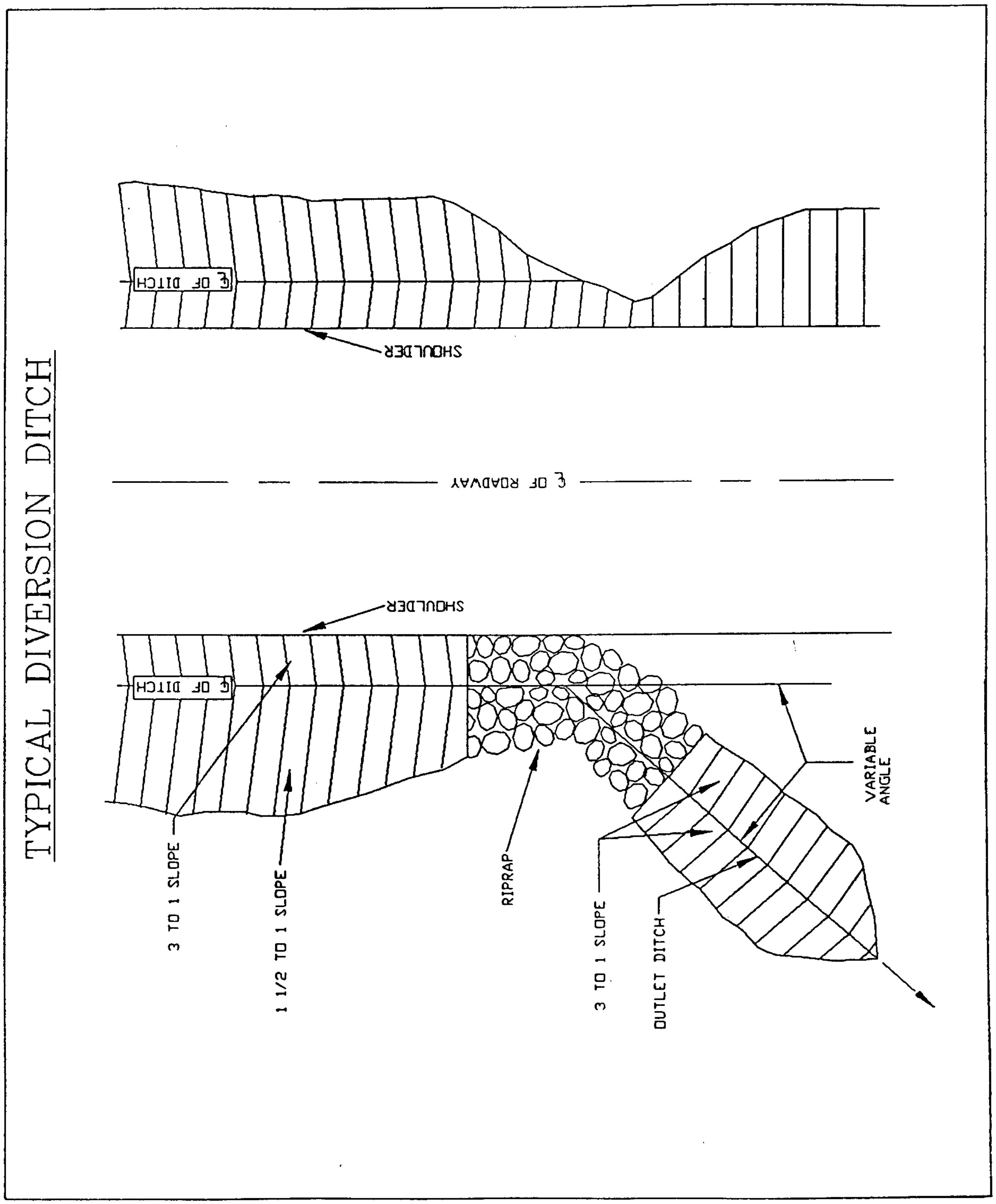
SHEET____OF____



TYPICAL RIPRAP DETAIL
OUTLET
INLET
SUBGRADE
RISE
1/2 RISE OR DIA. (APPROX.)
FILTER FABRIC
3:1
1'
4'
2'
BCCSP ARCH
1'-0"
LIMEROCK RIPRAP (CLASS I)
FLOW
STREAM BED
4'-0"
1'-0"
ELEVATION
LIMEROCK RIPRAP
℄ PIPE
10'-0"
INLET
OUTLET
2'-0"
FOR NEW CULVERTS CUT BOTH ENDS OF PIPE PER DETAIL "A"
VARIES
1'-0" (TYP.)
38"
DETAIL "A"
SHEET ____OF____

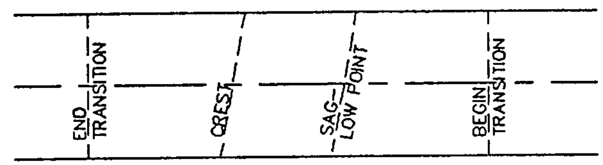

TYPICAL RIPRAP DETAIL
OUTLET
INLET
4:1
RISE
SUBGRADE
BCCSP ARCH 4:1
1'-0"
LIMEROCK RIPRAP (CLASS I)
FLOW
FILTER FABRIC
1/2 RISE OF DIA. (APPROX.)
2'
1'
4'
1'-0"
4'-0"
ELEVATION
NOTE: FORESLOPES SHALL BE 4:1
FOR NEW CULVERTS CUT BOTH ENDS OF PIPE PER DETAIL "A"
45"
33"
1'-0" (TYP.)
DETAIL "A"
(SEE RIPRAP NOTES ON SHEET___OF___)
LIMEROCK RIPRAP
℄ PIPE
℄ PIPE
2'-0"
3'-0"
10' - 0"
10' - 0"
10' - 0"
1/2 RISE OF DIA. APPROX.
SHEET ____OF____


TYPICAL PERCOLATION BASIN
NOT TO SCALE
SEE PLAN OR LINE DRAWING SHEETS FOR ACTUAL LENGTHS
25'
TRANSITION
BEG. STA
FOR BASIN
25'
TRANSITION
7.5'
TOP OF BACKSLOPE
EDGE OF SUBGRADE
℄ OF ROAD
PLAN VIEW
CLEARING LIMITS
SUBGRADE
7.5'
SEE NOTE 1
CONST. LIMITS
2%
5:1
1.5'
3:1
℄ ROAD
CROSS SECTION
NOTES:
1. CONSTRUCTION LIMIT IS 1' BEYOND TOP OF CUT OR 8' BEYOND BOTTOM OF DITCH, WHICHEVER DISTANCE IS GREATER.
2. PERCOLATION BASIN CONSTRUCTION CONSIDERED INCIDENTAL TO ITEM 306(02).
SHEET____OF____

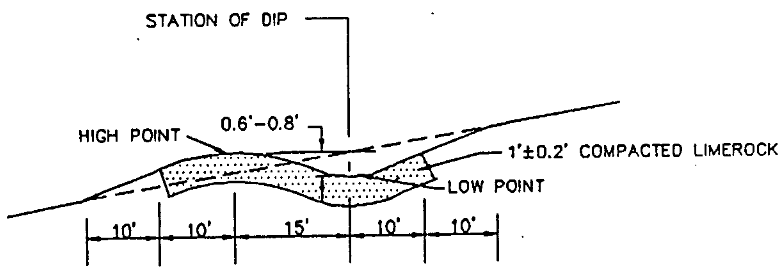


TYPICAL DIVERSION DITCH
℄ OF DITCH
SHOULDER
℄ OF ROADWAY
SHOULDER
℄ OF DITCH
3 TO 1 SLOPE
1 1/2 TO 1 SLOPE
RIPRAP
3 TO 1 SLOPE
OUTLET DITCH
VARIABLE ANGLE

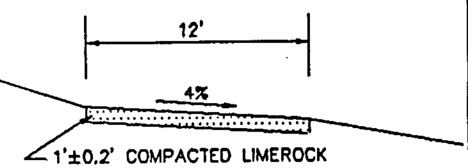
ROLLING DIP DETAIL



PLAN



PROFILE



SECTION AT LOW POINT

NOTES:

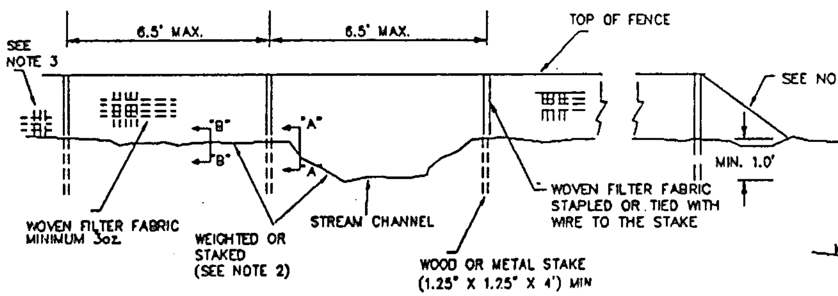
1. 15 CY OF LIMEROCK (TRUCK MEASURE) REQUIRED PER DIP
2. SEE PAGE 6 FOR SOURCES FOR LIMEROCK
3. ALL MATERIALS AND WORK INCIDENTAL TO SHALL BE PROVIDED BY THE CONTRACTOR AND PAID FOR UNDER PAY ITEM 619(16)

PAGE____OF____

EROSION CONTROL

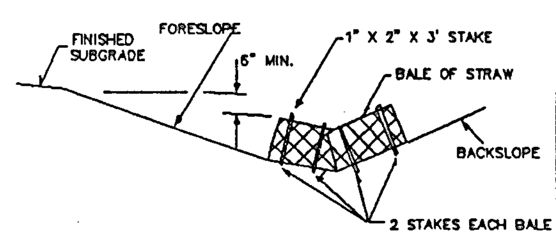
(PRE-FABRICATED)

TYPICAL SILT FENCE INSTALLATION



ELEVATION

TYPICAL STRAW BALE INSTALLATION



NOTE:

1. ACTUAL NUMBER OF STRAW BALES AND LOCATION TO BE DETERMINED BY ENGINEER.
2. STRAW BALES SHALL BE INSTALLED ACCORDING TO SECTION 204.

NOTES:

1. CONTRACTOR SHALL REMOVE FENCE AND SILT BY HAND UPON COMPLETION OF WORK. CONTRACTOR SHALL TAKE CARE TO REMOVE FENCE WITH MINIMUM OF SILT LEFT IN STREAM.
2. CONTRACTOR SHALL STAKE OR WEIGHT THE BOTTOM OF THE SILT FENCE. CONTRACTOR SHALL INSTALL WIRE TIE DOWNS AT THE ENDS OF THE FENCE TO SECURE THE TOP ELEVATION OF THE FILTER FABRIC.
3. SILT FENCE SHALL BE CONSTRUCTED AT LOCATIONS STAKED BY ENGINEER.
4. SILT FENCE SHALL BE ERECTED ACCORDING TO SECTION 204.
5. ALL SILT FENCE MATERIAL SHALL BE SUPPLIED BY THE CONTRACTOR.

SHEET____OF____

EROSION CONTROL

ITEM	TYPE	LB/ACRE	SEASON
SEED	PENSACOLA BAHIA BROWN TOP MILLET	40 12	2/15 – 9/15 2/15 – 9/15
	PENSACOLA BAHIA RYE GRASS	40 50	9/16 – 2/14 9/16 – 2/14
FERTILIZER	8-8-8	500	ALL
LIME	DOLOMITE	4000	ALL
MULCH	STRAW, HAY, OR PINE STRAW	4000	ALL

THE MULCH SHALL BE ANCHORED BY USE OF A CULTIPACKER

Appendix F
Army/Air Force Technical Manual Standards
TM 5-822-12 and Portions of TM 5-822-2/AFM 88-7

TECHNICAL MANUAL

No. 5-822-12

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC, *28 September 1990*

DESIGN OF AGGREGATE SURFACED ROADS AND AIRFIELDS

Approved for public release; distribution is unlimited

LIST OF TABLES

DESIGN OF AGGREGATE SURFACED ROADS AND AIRFIELDS

1. Purpose

This manual presents the procedures for design of aggregate surfaced roads and airfields.

2. Scope

This manual presents criteria for determining the thickness, material, and compaction requirements for all classes of aggregate surfaced roads and for Class I, II, and III airfields at US Army installations. Road classes are defined in TM 5-822-2, and airfield classes are defined in TM 5-803-4. Class IV Army airfields would normally be paved. Use of the term roads includes roads, streets, open storage areas, and parking areas. Use of the term airfields includes heliports, runways, taxiways, and parking aprons. Design requirements are presented for frost and nonfrost areas.

3. References

Publications cited in this manual are listed in appendix A.

4. Design of aggregate surfaced roads

a. Procedures. The thickness design of aggregate surfaced roads is similar to the design of flexible pavement roads as contained in TM 5-822-5. This procedure involves assigning a class to the road being designed based upon the number of vehicles per day. A design category is then assigned to the traffic from which a design index is determined. This design index is used with figure 1 to select the thickness (minimum of 4 inches) of aggregate required above a soil with a given strength expressed in terms of California Bearing Ratio (CBR) for nonfrost areas or in terms of a frost area soil support index (FASSI) in frost areas.

b. Classes of roads. The classes of aggregate surfaced roads vary from A to G. Selection of the proper class depends upon the traffic intensity and is determined from table 1.

c. Design index. The design of gravel roads will be based on a design index, which is an index representing all traffic expected to use the road during its life. The design index is based on typical magnitudes and compositions of traffic reduced to equivalents in terms of repetitions of an 18,000-pound single-axle, dual-wheel load. For designs involving rubber-tired vehicles, traffic is classified in three groups as follows:

Group 1. Passenger cars and panel and pickup trucks.

Group 2. Two-axle trucks.

Group 3. Three-, four-, and five-axle trucks.

Traffic composition will then be grouped in the following categories:

Category I. Traffic composed primarily of passenger cars, panel and pickup trucks (Group 1 vehicles), and containing not more than 1 percent two-axle trucks (Group 2 vehicles).

Category II. Traffic composed primarily of passenger cars, panel and pickup trucks (Group 1 vehicles), and containing as much as 10 percent two-axle trucks (Group 2 vehicles). No trucks having three or more axles (Group 3 vehicles) are permitted in this category.

Category III. Traffic containing as much as 15 percent trucks, but with not more than 1 percent of the total traffic composed of trucks having three or more axles (Group 3 vehicles).

Category IV. Traffic containing as much as 25 percent trucks, but with not more than 10 percent of the total traffic composed of trucks having three or more axles (Group 3 vehicles).

Category IVA. Traffic containing more than 25 percent trucks or more than 10 percent trucks having three or more axles (Group 3 vehicles).

d. Tracked vehicles and forklift trucks. Tracked vehicles having gross weights not exceeding 15,000 pounds and forklift trucks having gross weights not exceeding 6,000 pounds may be treated as two-axle trucks (Group 2 vehicles) in determining the design index. Tracked vehicles having gross weights exceeding 15,000 pounds but not 40,000 pounds and forklift trucks having gross weights exceeding 6,000 pounds but not 10,000 pounds may be treated as Group 3 vehicles in determining the design index. Traffic composed of tracked vehicles exceeding 40,000-pound gross weight and forklift trucks exceeding 10,000-pound gross weight has been divided into the following three categories:

Maximum Vehicle Gross Weight, pounds

Category	Tracked Vehicles	Forklift Trucks
V	60,000	15,000
VI	90,000	20,000
VII	120,000	35,000

e. Design index. The design index to be used in designing a gravel road for the usual pneumatic-tired vehicles will be selected from table 2.

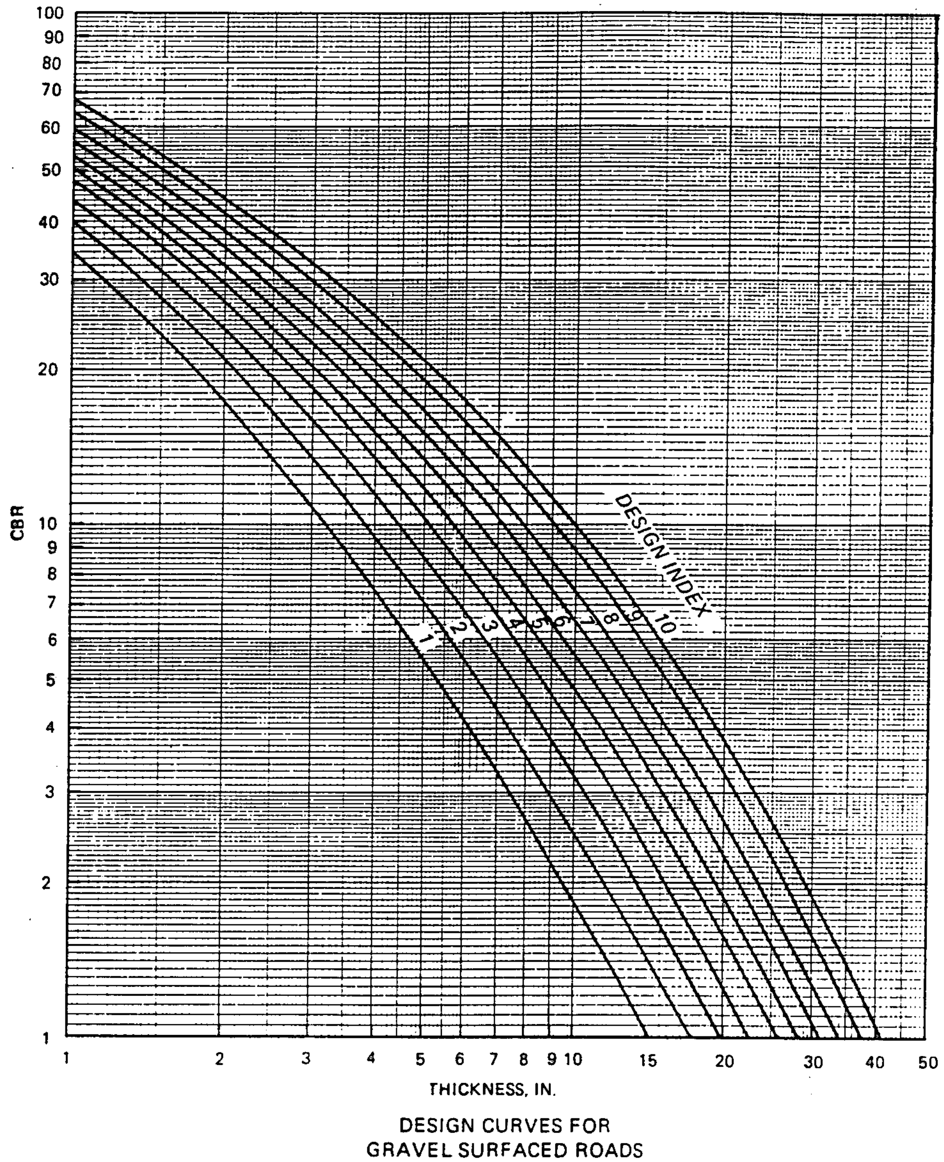


Figure 1. Thickness design curves for aggregate surfaced roads.

f. Roads for tracked vehicles. Roads sustaining traffic of tracked vehicles weighing less than 40,000 pounds, and forklift trucks weighing less than 10,000 pounds, will be designed in accordance with the pertinent class and category from table 2. Roads sustaining traffic of tracked vehicles, heavier than 40,000 pounds, and forklift trucks heavier than 10,000 pounds, will be designed in accordance with the traffic intensity and category from table 3.

g. Design life. The life assumed for design is 25 years. For a design life less than 5 years, the design indexes in tables 2 and 3 may be reduced by one. Design indexes below three should not be reduced.

h. Entrances, exits, and segments. Regardless of the design class selected for hardstands, special consideration should be given to the design of approach roads, exit roads, and other heavily trafficked areas. Failure or poor performance in these channelized traffic areas

Table 1. *Criteria for selecting aggregate surface road class.*

Road Class	Number of Vehicles per day
A	10,000
B	8,400 – 10,000
C	6,300 – 8,400
D	2,100 – 6,300
E	210 – 2,100
F	70 – 210
G	under 70

Table 2. *Design index for pneumatic-tired vehicles.*

	Design Index			
Class	Category I	Category II	Category III	Category IV
A	3	4	5	6
B	3	4	5	6
C	3	4	4	6
D	2	3	4	5
E	1	2	3	4
F	1	1	2	3
G	1	1	1	2

Table 3. *Design index for tracked vehicles and forklift trucks.*

	Number of Vehicles per Day (or Week as indicated)							
Traffic Category	500	200	100	40	10	4	1	1 Per Week
V	8	7	6	6	5	5	5	—
VI	—	9	8	8	7	6	6	5
VII	—	—	10	10	9	8	7	6

often has greater impact than localized failure on the hardstand itself. Since these areas will almost certainly be subjected to more frequent and heavier loads than the hardstand, the design index used for the primary road should be used for entrances and exits to the hardstand. In the case of large hardstands having multiple use and multiple entrances and exits, consideration should be given to partitioning and using different classes of design. The immediate benefits that would accrue include economy through elimination of overdesign in some areas and better organization of vehicles and equipment.

i. Thickness criteria (nonfrost areas). Thickness requirements for aggregate surfaced roads are determined from figure 1 for a given soil strength and design index. The minimum thickness requirement will be 4 inches. Figure 1 will be entered with the CBR of the subgrade to determine the thickness of aggregate required for the appropriate design index. The thickness determined from the figure may be constructed of compacted granular fill for the total depth over the natural subgrade or in a layered system of granular fill (including subbases) and compacted subgrade for the same total depth. The layered section should be checked to ensure that an adequate thickness of material is used to protect the underlying layer based on the CBR of the underlying layer. The granular fill may consist of base and subbase material provided the top 6 inches meet the gradation requirements in paragraph 8.

5. Design of aggregate surfaced airfields

The thickness design of aggregate surfaced airfields is similar to the design of flexible pavement airfields as contained in TM 5-825-2. This procedure involves assigning a class to the airfield based upon the aircraft controlling the design. Having selected the class of airfield, the design is accomplished using figures 2 through 4.

a. Classes of airfields. There are four classes of Army airfields. These are Classes I–IV, although only Classes I–III are considered candidates for aggregate surfacing. Each class of airfield is designed for a standard loading condition and pass level as defined in TM 5-803-4. Where necessary, airfields may be designed for loads and pass levels other than the standard, and the criteria herein provide thicknesses for varying pass and load levels.

b. Traffic areas. Army airfields are divided into traffic areas for design purposes. Type B traffic areas consist of taxiways, the first 1,000 feet of runway ends, and aprons. Type C traffic areas are the interior portions of the runway (between the 1,000 foot runway ends).

c. Thickness criteria (nonfrost areas). Thickness requirements for aggregate surfaced airfields are determined from figures 2 through 4 for types B and C traffic areas. Thicknesses for type B areas are determined directly from the curves, and type C traffic areas are designed using 75 percent of the load used to design type B traffic areas. The minimum thickness requirement for all cases will be 4 inches. The figure for the appropriate airfield class will be entered with the subgrade CBR to determine the thickness required for a given load and pass level. The thickness determined from the figure may be constructed of compacted granular fill for the total depth over the natural subgrade or in a layered system of granular fill and compacted subgrade for the same total depth. The layered section should be checked to ensure that an adequate thickness of material is used to protect the underlying layer based upon the CBR of the underlying layer. The granular fill may consist of base and subbase material provided the top 6 inches meet the gradation requirements of paragraph 8.

6. Design CBR for select materials and subbases

Design CBR values and materials requirements for select materials and subbases are to be selected in accordance with TM 5-825-2 except as modified in table 4.

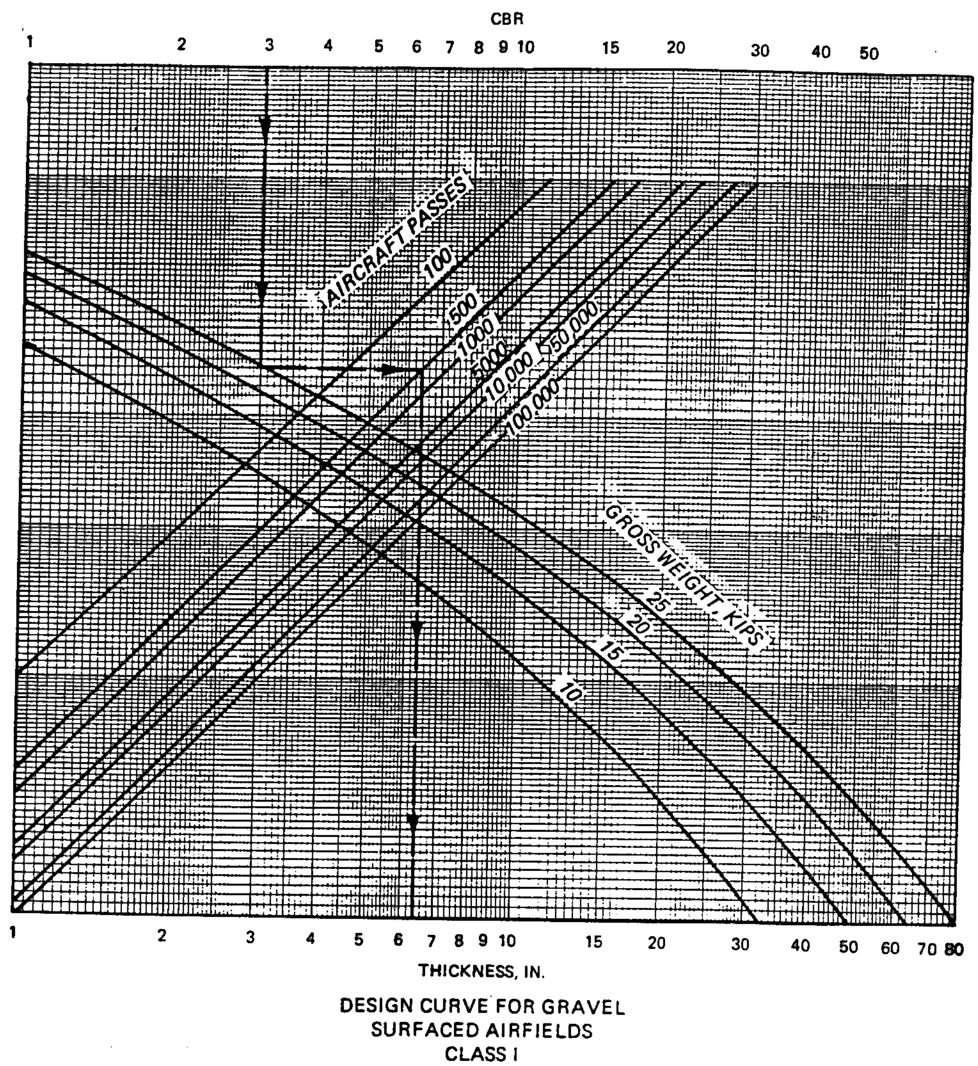


Figure 2. Aggregate surfacing design curve for Class I airfields.

7. Frost area considerations

In areas where frost effects have an impact on the design of pavements, additional considerations concerning thicknesses and required layers in the pavement structure must be addressed. The specific areas where frost has an impact on the design are discussed in the following paragraphs; however, a more detailed discussion of frost effects is presented in TM 5-818-2. For frost design purposes, soils have been divided into eight groups as shown in table 5. Only the nonfrost-susceptible (NFS) group is suitable for base course. NFS, S1, or S2 soils may be used for subbase course, and any of the eight groups may be encountered as subgrade soils. Soils are listed in approximate order of decreasing bearing capability during periods of thaw.

a. Required thickness. Where frost susceptible subgrades are encountered, the section thickness required will be determined according to the reduced subgrade strength method. The reduced subgrade strength method requires the use of frost area soil support indexes listed in table 6. Frost-area soil support indexes are used as if they were CBR values; the term CBR is not applied to them, however, because, being weighted average values for an annual cycle, their values cannot be determined by CBR tests. Figures 1 through 4 are entered with the soil support indexes in place of CBR values to determine the required section thickness.

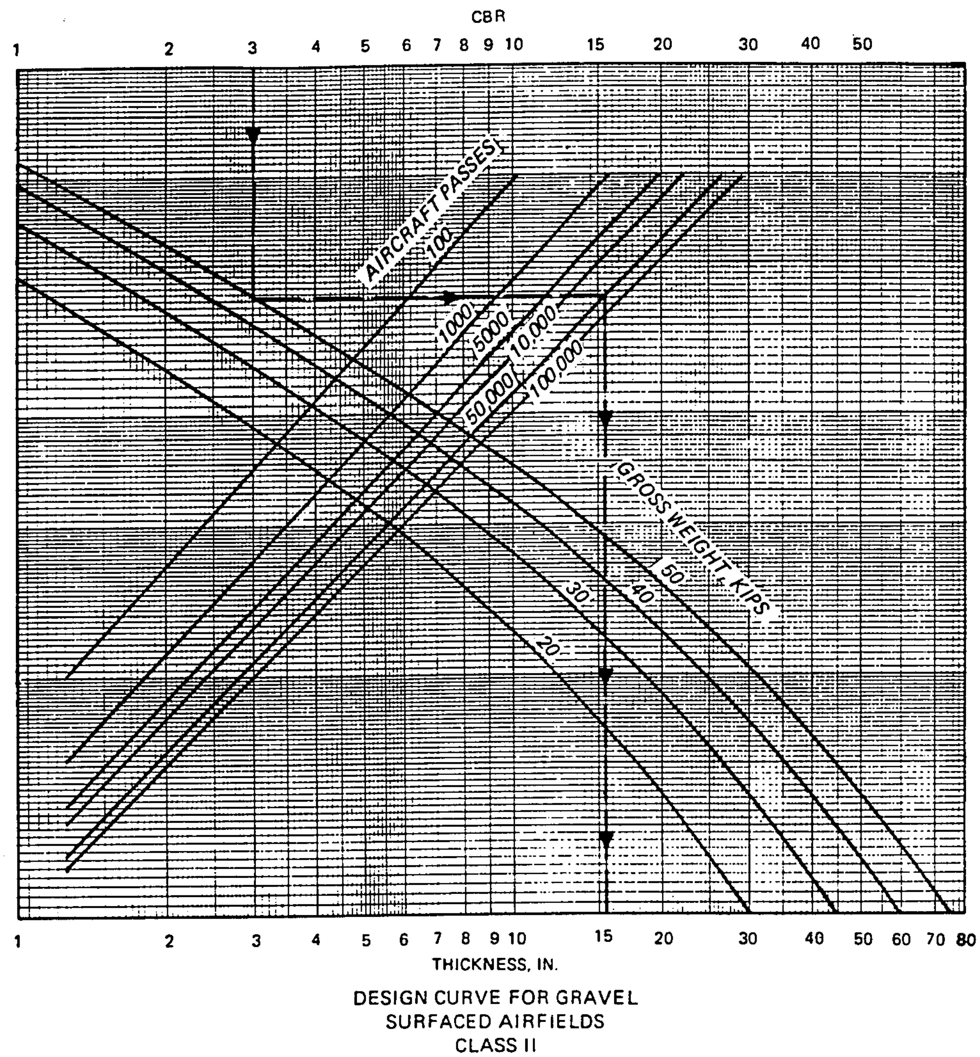


Figure 3. Aggregate surfacing design curve for Class II airfields.

b. Required layers in pavement section. When frost is a consideration, it is recommended that the pavement section consist of a series of layers that will ensure the stability of the system, particularly during thaw periods. The layered system in the aggregate fill may consist of a wearing surface of fine crushed stone, a coarse-graded base course, and/or a well-graded subbase of sand or gravelly sand. To ensure the stability of the wearing surface, the width of the base course and subbase should exceed the final desired surface width by a minimum of 1 foot on each side.

c. Wearing surface. The wearing surface contains fines to provide stability in the aggregate surface. The presence of fines helps the layer's compaction characteristics and helps to provide a relatively smooth riding surface.

d. Base course. The coarse-graded base course is important in providing drainage of the granular fill. It is also important that this material be nonfrost-susceptible so that it retains its strength during spring thaw periods.

e. Subbase. The well-graded sand subbase is used for additional bearing capacity over the frost-susceptible subgrade and as a filter layer between the coarse-graded base course and the subgrade to prevent the migration of the subgrade into the voids in the coarser material during periods of reduced subgrade strength. The material must therefore meet standard filter criteria.

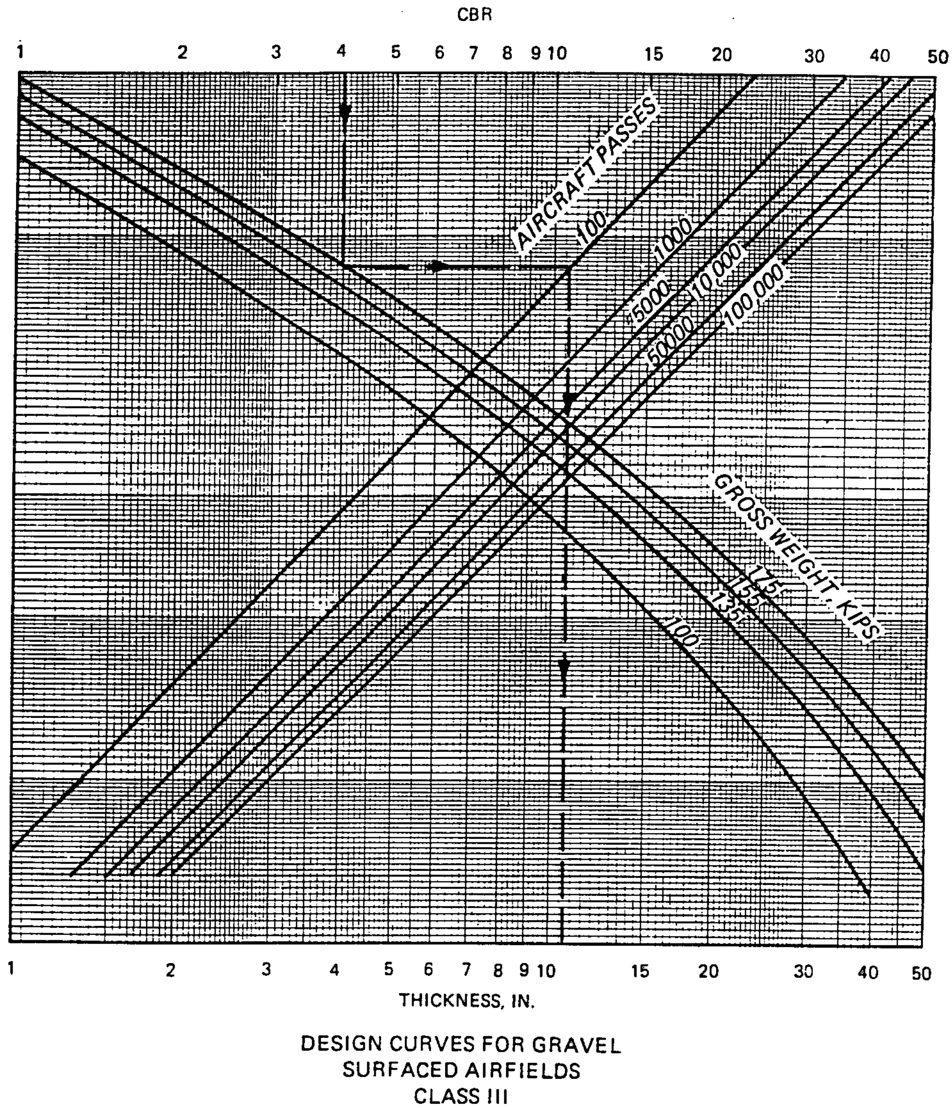


Figure 4. Aggregate surfacing design curve for Class III airfields.

The sand subbase must be either nonfrost-susceptible or of low frost susceptibility (S1 or S2). The filter layer may or may not be necessary depending upon the type of subgrade material. If the subgrade consists principally of gravel or sand, the filter layer may not be necessary and may be replaced by additional base course if the gradation of the base course is such that it meets filter criteria. However, for finer grained soils, the filter layer will be necessary. If a geotextile is used, the sand subbase/filter layer may be omitted as the fabric will be placed directly on the subgrade and will act as a filter.

f. Compaction. The subgrade should be compacted to provide uniformity of conditions and a firm working platform for placement and compaction of subbase. Compaction of subgrade will not change its frost-area soil support index, however, because frost action will cause the subgrade to revert to a weaker state. Hence, in frost areas, the compacted subgrade will not be considered part of the layered system of the road or airfield which should be comprised of only the wearing, base, and subbase courses.

g. Thickness of base course and filter layer. Relative thicknesses of the base course and filter layer are

Table 4. Maximum permissible values for subbases and select materials.

	Maximum Permissible Value					
			Gradation Requirements Percent Passing			
Material	Maximum Design CBR	Size inch	No. 10 Sieve	No. 200 Sieve	Liquid Limit*	Plasticity Index*
Subbase	50	2	50	15	25	5
Subbase	40	2	80	15	25	5
Subbase	30	2	100	15	25	5
Select material	20	3	—	—	35	12

*Determinations of these values will be made in accordance with ASTM D 4318.

variable, and should be based on the required cover and economic considerations.

h. Alternate design. The reduced subgrade strength design procedure provides the thickness of soil required above a frost-susceptible subgrade to minimize frost heave. To provide a more economical design, a frost susceptible select material or subbase may be used as a part of the total thickness above the frost-susceptible subgrade. However, the thickness above the select material or subbase must be determined by using the FASSI of the select or subbase material. Where frost-susceptible soils are used as select materials or subbases, they must meet the requirements of current specifications except that the restriction on the allowable percent finer than 0.02 mm is waived.

8. Surface course requirements

The requirements for the various materials to be used in the construction of aggregate surfaced roads and airfields are dependent upon whether or not frost is a consideration in the design.

a. Nonfrost areas. The material used for gravel-surfaced roads and airfields should be sufficiently cohesive to resist abrasive action. It should have a liquid limit no greater than 35 and a plasticity index of 4 to 9. It should also be graded for maximum density and minimum volume of voids in order to enhance optimum moisture retention while resisting excessive water intrusion. The gradation, therefore, should consist of the optimum combination of coarse and fine aggregates that will ensure minimum void ratios and maximum density. Such a material will then exhibit cohesive strength as well as intergranular shear strength. Recommended gradations are as shown in table 7. If the fine fraction of the material does not meet plasticity characteristics, modification by addition of chemicals might be required. Chloride products can, in some cases, enhance moisture retention, and lime can be used to reduce excessive plasticity.

b. Frost areas. As previously stated, where frost is a consideration in the design of roads and airfields, a layered system should be used. The percentage of fines should be restricted in all the layers to facilitate drainage and reduce the loss of stability and strength during thaw periods. Gradation numbers 3 and 4 shown in table 7 should be used with caution since they may be unstable in a freeze-thaw environment.

9. Compaction requirements

Compaction requirements for the subgrade and granular layers are expressed as a percent of maximum CE 55 density as determined by using MIL-STD-621 Test Method 100. For the granular layers, the material will be compacted to 100 percent of the maximum CE 55 density. Select materials and subgrades in fills shall have densities equal to or greater than the values shown in tables 8 and 9 for roads and table 10 for airfields except that fills will be placed at no less than 95 percent compaction for cohesionless soils ($PI \leqq 5$; $LL \leqq 25$) or 90 percent compaction for cohesive soils ($PI > 5$; $LL > 25$). Subgrades in cuts shall have densities equal to or greater than the values shown in tables 8 through 10. Subgrades occurring in cut sections will be either compacted from the surface to meet the densities shown in tables 8 through 10, removed and replaced before applying the requirements for fills, or covered with sufficient material so that the uncompacted subgrade will be at a depth where the in-place densities are satisfactory. The depths shown in tables 8 through 10 are measured from the surface of the aggregate road or airfield and not the surface of the subgrade.

10. Drainage requirements

Adequate surface drainage should be provided in order to minimize moisture damage. Expeditious removal of surface water reduces the potential for absorption and ensures more consistent strength and reduced maintenance. Drainage, however, must be provided in a manner to preclude damage to the aggregate surfaced road or airfield through erosion of fines or erosion of the entire surface layer. Also, care must be taken to ensure that the change in the overall drainage regime as a result of construction can be accommodated by the surrounding topography without damage to the environment or to the newly constructed road or airfield.

a. The surface geometry of a road or airfield should be designed so that drainage is provided at all points. Depending upon the surrounding terrain, surface drainage of the roadway can be achieved by a continual cross slope or by a series of two or more interconnecting cross slopes. The entire area should consist of one or more cross slopes having a gradient that meet the requirements of TM 5-820-1 and TM 5-820-4. Judgement will be required to arrange the cross slopes in a manner to remove water from the road or airfield at the nearest

Table 5. Frost design soil classification.

Frost Group	Kind of Soil	Percentage Finer Than 0.02 mm by Weight	Typical Soil Types Under Unified Soil Classification System
NFS*	(a) Gravels Crushed stone Crushed rock	0-1.5	GW, GP
	(b) Sands	0-3	SW, SP
PFS**	(a) Gravels Crushed stone Crushed rock	1.5-3	GW, GP
	(b) Sands	3-10	SW, SP
S1	Gravelly soils	3-6	GW, GP, GW-GM, GP-GM
S2	Sandy soils	3-6	SW, SP, SW-SM, SP-SM
F1	Gravelly soils	6 to 10	GM, GW-GM, GP-GM
F2	(a) Gravelly soils (b) Sands	10 to 20 6 to 15	GM, GW-GM, GP-GM SM, SW-SM, SP-SM
F3	(a) Gravelly soils (b) Sands, except very fine silty sands (c) Clays, PI > 12	Over 20 Over 15 --	GM, GC SM, SC CL, CH
F4	(a) All silts (b) Very fine silty sands (c) Clays, PI < 12 (d) Varved clays and other fine-grained banded sediments	-- Over 15 -- --	ML, MH SM CL, CL-ML CL and ML CL, ML, and SM CL, CH, and ML CL, CH, ML and SM

*Nonfrost-susceptible.
**Possibly frost-susceptible, but requires laboratory test to determine frost design soil classification.

Table 6. Frost-area soil support indexes of subgrade soils.

Frost Group of Subgrade Soils	Frost Area Soil Support Index
F1 and S1	9.0
F2 and S2	6.5
F3 and F4	3.5

possible points while taking advantage of the natural surface geometry to the greatest extent possible.

b. Adequate drainage must be provided outside the road or airfield area to accommodate maximum possible drainage flow from the road or airfield. Ditches and culverts will be provided for this purpose. Culverts should be used sparingly and only in areas where adequate cover of granular fill is provided over the culvert. Additionally, adjacent areas and their drainage

Table 7. Gradation for aggregate surface courses.

Sieve Designation		No. 1	No. 2	No. 3	No. 4
25.0 mm	1 in.	100	100	100	100
9.5 mm	3/8 in.	50–85	60–100	—	—
4.7 mm	No. 4	35–65	50–85	55–100	70–100
2.00 mm	No. 10	25–50	40–70	40–100	55–100
0.425 mm	No. 40	15–30	24–45	20–50	30–70
0.075 mm	No. 200	8–15	8–15	8–15	8–15

Note: The percent by weight finer than 0.02 mm shall not exceed 3 percent.

Table 8. Compaction requirements for roads, cohesive soils.

Percent Compaction	Depth of Compaction (in inches) for Indicated Design Index: 1	2	3	4	5	6	7	8	9	10
100	2	3	3	3	4	4	4	5	5	6
95	4	5	5	6	7	7	8	9	10	11
90	6	7	8	9	10	11	12	13	15	17
85	7	9	10	12	13	15	16	18	20	22
80	9	11	13	14	16	18	20	22	25	27

provisions should be evaluated to determine if rerouting is needed to prevent water from other areas flowing across the road or airfield.

c. Drainage is a critical factor in aggregate surface road or airfield design, construction, and maintenance. Therefore, drainage should be considered prior to construction, and when necessary, serve as a basis for site selection.

11. Maintenance requirements

The two primary causes of deterioration of aggregate surfaced roads requiring frequent maintenance are the environment and traffic. Rain or water flow will wash fines from the aggregate surface and reduce cohesion, while traffic action causes displacement of surface materials. Maintenance should be performed at least every 6 months and more frequently if required. The frequency of maintenance will be high for the first few years of use but will decrease over time to a constant value. The majority of the maintenance will consist of periodic grading to remove the ruts and potholes that will inevitably be created by the environment and traffic and to replace fines. Occasionally during the lifetime of the road or airfield, the surface layer may have to be scarified, additional aggregate added to increase the thickness back to that originally required, and the wearing surface recompacted to the specified density.

12. Dust control

a. Objective. The primary objective of a dust palliative is to prevent soil particles from becoming airborne as a result of wind or traffic. Where dust palliatives are considered for traffic areas, they must withstand the abrasion of the wheels or tracks. An important factor limiting the applicability of the dust palliative in traffic areas is the extent of surface rutting or abrasion that will occur under traffic. Some palliatives will tolerate deformations better than others, but normally ruts in excess of 1/2 inch will result in the virtual destruction of any thin layer or shallow-depth penetration dust palliative treatment. The abrasive action of tank tracks may be too severe for use of some dust palliatives in a traffic area.

b. A wide selection of materials for dust control is available to the engineer. No one choice, however, can be singled out as being the most universally acceptable for all problem situations that may be encountered. However, several materials have been recommended for use and are discussed in TM 5-830-3.

Table 9. Compaction requirements for roads, cohesionless soils.

Percent Compaction	Depth of Compaction (in inches) for Indicated Design Index: 1	2	3	4	5	6	7	8	9	10
100	4	5	5	6	7	7	8	9	10	11
95	7	8	10	11	12	14	15	17	19	21
90	10	12	14	16	18	20	22	24	28	30
85	13	16	18	21	23	26	29	31	35	38

Table 10. Compaction requirements for airfields.

Airfield Type	Traffic Area	Depth Below Pavement Surface, in. — Cohesive Soils, percent: 100	95	90	85	80	Cohesionless Soils, percent: 105	100	95	90	85
Class I	B	4	6	8	10	12	2	6	10	13	16
	C	3	5	7	9	10	1	5	8	11	14
Class II	B	5	8	12	15	19	2	8	14	21	26
	C	4	7	10	13	16	2	7	12	17	23
Class III	B	9	15	21	27	34	4	15	25	37	48
	C	7	12	17	22	29	3	12	21	31	41

13. Design examples No. 1. Assume the following conditions:

CBR values.

—Natural subgrade = 5 (CL material with PI = 15, Frost group F3).
—Compacted subgrade = 8.
—Fines graded crushed rock wearing surface = 80.

—Coarse graded crushed rock base course = 80.
—Clean sand subbase = 15.

Anticipated traffic.

—40 passes per day of 60-ton tracked vehicles.

Calculations:

a. From paragraph 4.d, select the traffic category for a 120,000-pounds tracked vehicle as Category VII.

b. The design index is then determined from table 3 to be 10 for 40 passes per day and Category VII traffic.

c. The required thickness of the tank trail is determined from figure 1. The following sections would be adequate if the natural subgrade has the required in-place density.

	7 inches crushed rock
17 inches crushed rock	10 inches sand subbase CBR = 15
Natural subgrade CBR = 5	Natural subgrade CBR = 5

d. Where the subgrade is compacted to a CBR of 8, the following sections would be satisfactory:

12 inches crushed rock	7 inches crushed rock
	5 inches sand subbase CBR = 15
5 inches compacted subgrade CBR = 8	5 inches compacted subgrade CBR = 8
Natural subgrade CBR = 5	Natural subgrade CBR = 5

e. In areas where frost is not a factor in the design of roads, the sections shown above are adequate, and the most economical should be used. The granular material should conform to the material requirements for nonfrost areas previously discussed. If available, subbase materials other than the clean sand may be used for adjusting the sections.

f. Determine the surface geometry of the tank trail in a severely cold area where subgrade freezing is predicted.

g. In areas where frost is a consideration, the tank trail should consist of the following layers:

—A wearing surface of fine-graded crushed rock.
—A base course of coarse-graded crushed rock.
—A subbase of well-graded sand, frost group soils F1 and F2, or geotextile.

As previously stated, the function of the last layer as a filter layer is not always required, depending upon the subgrade material. In this case the subgrade is a CL; therefore, it is required. According to table 6, the frost-area soil support index for an F3 subgrade soil is 3.5. With the exception of the wearing surface layer which will vary between 4 and 6 inches, the other layers are varied based on economic factors. However, the required thickness of cover over the various layers must be satisfied. Also, the minimum thickness of each layer should be 4 inches.

h. Possible alternatives for the tank trail section based on frost considerations might be:

(1) Using sand subbase. From figure 1 using a frost-area soil support index of 3.5 and a design index of 10, the total thickness required above the subgrade equals 21.0 inches. Also from figure 1, the minimum required cover over the NFS, S1, or S2 sand subbase (CBR = 15) is 7.0 inches. Using a minimum layer thickness of 4 inches in the wearing surface and the course graded base course, the actual cover required will be 8 inches. Therefore, the section might be:

4 inches fine-graded stone
4 inches coarse-graded crushed stone
13 inches well-graded sand subbase (CBR = 15)
Subgrade

(2) An alternative section might be to construct the wearing course and subbase to a minimum thickness of 4 inches.

4 inches fine-graded stone
13 inches coarse-graded crushed stone
4 inches well-graded sand subbase
Subgrade

(3) Using F1 and F2 soils. As previously stated, frost group soils F1 and F2 may be used in the lower part of the granular material over F3 and F4 subgrade soils. The thickness of F2 base material should not exceed the difference between the thickness required over F3 and the thickness required over an F2 subgrade. The minimum required cover over F1 soils is 11 inches, over F2 soils is 14 inches, and over F3 soils is 21 inches. Using a minimum layer thickness of 4 inches, the following section may be used:

4 inches fine-graded stone
7 inches coarse-graded crushed stone
4 inches frost group soil F1
6 inches frost group soil F2
Subgrade - F3

For economy, based on material availability, these sections may be altered as long as a higher-quality material is used above a lesser-quality material. For example, crushed stone could be substituted for the F1 soil.

(4) Using geotextiles. Either of the designs shown above could be used by deducting 6 inches of well-graded sand subbase and replacing it with a geotextile. The total thickness above the geotextile must be a minimum of 15 inches. Alternative designs using a geotextile might be:

4 inches fine-graded stone

11 inches coarse-graded crushed stone

geotextile

Subgrade

or:

7 inches fine-graded stone

8 inches well-graded sand

geotextile

Subgrade

Notes:

- —All layer depths should be rounded up to the next full inch for construction purposes.
- —The granular layers should be compacted to 100 percent CE 55 maximum density.
- —The subgrade should be compacted to the density required by table 8.
- —The material should meet the gradation requirements shown herein.
- —The frost group soils F1 and F2 used as base and subbase materials should meet the requirements in the appropriate guide specifications.
- —As previously stated, after all possible design sections are determined, the final section used for the tank trail should be determined on the basis of an economic analysis.

14. Design Example No. 2. Assume the following conditions:

CBR values.

- —Natural subgrade = 4 (SM – silty sand material, frost group F2).
- —Compacted subgrade = 8.
- —Fine-graded crushed rock wearing surface = 80.
- —Course-graded crushed rock base course = 80.
- —Clean sand subbase = 15.

Projected traffic.

- —2,500 operations per day of Category IV traffic.

Calculations:

a. Determine the required thickness. From table 1 determine the road to be a Class D road. From table 3, select a design index = 5. From the design curves (figure 1) the required thickness above the natural subgrade with a CBR of 4 is 11.5 inches (round to next full inch of 12); the required cover over the compacted subgrade (CBR = 8) is 7 inches. Therefore, the hardstand might have the following cross sections:

12.0 inches crushed rock	4 inches crushed rock	7 inches crushed rock
	8.0 inches sand subbase	Compacted subgrade CBR = 8
Subgrade CBR = 4	Subgrade CBR = 4	

b. Determine the cross section in a severely cold area where subgrade freezing is predicted.

(1) Only the wearing surface and base course layers will apply in this section. The sand subbase is not required because the subgrade is not cohesive. The filter fabric will not be used because the subgrade soil is an F2 material and the use of this fabric is restricted to F3 and F4 subgrade soils.

(2) In this case the natural subgrade CBR of 4 is less than the frost-area soil support index and will govern the design. The total thickness required above a subgrade CBR = 4 is 12.0 inches.

(3) Therefore, the cross section for this condition will be:

4 inches fine-graded stone

8.0 inches coarse-graded crushed stone

Subgrade CBR = 4

c. Based on economic considerations, alternative sections may be developed using frost group soils S1, S2, and F1 with lower portion of the base material. An example using F1 soils is as follows:

7.0 inches fine-graded stone

5 inches frost group soil F1

Subgrade CBR = 4

15. Design Example No. 3. Assume the following conditions:

Design is for Army Class III airfield.

Traffic protection = 10,000 passes of C-130 aircraft.

Design gross weight = 135 kips.

CBR values.

- —Subgrade = 6
- —Crushed stone = 80

Enter figure 4 with the subgrade CBR of 6, the 135 kip gross weight and 10,000 passes, and read the thickness required above the 6 CBR of 13.5 inches which when rounded to the next full inch will be 14.0 inches. The section therefore would be:

14.0 inches of crushed stone

Subgrade CBR = 6

APPENDIX A
REFERENCES

Government Publications

Department of Defense

MIL-STD-621A, Notices 1, 2	Test Method for Pavement Subgrade, Subbase, and Base-Course Materials

Departments of the Army, Navy, and Air Force

TM 5-803-4	Planning of Army Aviation Facilities
TM 5-818-2	Pavement Design of Seasonal Frost Areas
TM 5-820-1/AFM 88-5, Chap. 1	Surface Drainage Facilities for Airfields and Heliports
TM 5-820-4/AFM 88-5, Chap. 4	Drainage for Areas Other Than Airfields
TM 5-822-2/AFM 88-7, Chap. 5	General Provisions and Geometric Design for Roads, Streets, Walks, and Open Storage Areas
TM 5-822-5/AFM 88-7, Chap. 3	Flexible Pavements for Roads, Streets, Walks and Open Storage Areas
TM 5-825-2/AFM 86-6, Chap. 2/ NAVFAC DM 21.3	Flexible Pavement Design for Airfields
TM 5-830-3	Dust Control for Roads, Airfields, and Adjacent Areas

Nongovernment Publications

American Society for Testing and Materials (ASTM): 1916 Race Street, Philadelphia, PA 19103

D 4318-83	Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

The proponent agency of this publication is the Office of the Chief of Engineers, United States Army. Users are invited to send comments and suggested improvements on DA Form 2028 (Recommended Changes to Publications and Blank Forms) to HQUSACE (CEMP-ET), WASH, D.C. 20314-1000.

By Order of the Secretary of the Army:

CARL E. VUONO
General, United States Army
Chief of Staff

Official:
THOMAS F. SIKORA
Brigadier General, United States Army
The Adjutant General

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CHAPTER 1
INTRODUCTION

1-1. Purpose and scope. This manual establishes general provisions and geometric design criteria for guidance in the design of roads, streets, walks, and open storage areas at military installations.

1-2. Definitions. The definitions presented below are included to prevent misunderstanding and confusion resulting from the wide variation in meaning of various terms in local, regional, and general use. More comprehensive lists of definitions are presented in the manuals of the American Association of State Highway and Transportation Official (AASHTO) and the Transportation Research Board.

a. Public way and storage area designations.

(1) *Highway.* A general term denoting a public way for purpose of vehicular travel including the entire area within the right-of-way.

(2) *Road.* A term applied to highways in open areas. Open areas are defined in i.(2) below.

(3) *Street.* A term applied to highways in built-up areas. Built-up areas are defined in i.(1) below.

(4) *Walks.* Graded strips between buildings and other facilities adequately surfaced for all-weather use by pedestrians.

(5) *Open storage areas.* Areas planned and designed for storing, servicing, and parking of organizational vehicles; or for parking of visitors' vehicles, civilian employees, and attached personnel; or for receiving, classifying, and storing of supplies, new and salvaged materials, and equipment pending assignment for use or distribution; or for salvaging, processing, or repairing of equipment.

(6) *Hardstand.* Paved portions of open storage areas excluding roadways or service traffic lanes.

b. Highway designations. Highways can be designated according to location: access, replacement, and installation; cross-section design: undivided and divided; or directional usage: one-way and two-way.

(1) *Access.* An access highway is an existing or proposed public highway which is needed to provide highway transportation services from a military reservation to suitable transportation facilities. This will not include installation highways within the boundary of a military reservation that has been dedicated to public use if reasonable assurance can be given that future closure to public use will not be required.

(2) *Replacement.* A replacement is a public highway that must be constructed to replace a public street or road that has been or will be closed to public use because of the construction or expansion of a military installation or because of security restrictions.

(3) *Installation.* Installation highways include all roads and streets within the site limits of military installations which are constructed and maintained by the Department of Defense. All installation highways are classified in accordance with their relative importance to the installation as a whole and with respect to the composition, volume, and characteristics of the traffic using them.

(4) *Undivided.* An undivided road or street is a roadway having no natural or structural barrier separating traffic moving in opposite directions.

(5) *Divided.* A divided highway is a two-directional roadway having a natural or structural barrier separating traffic moving in opposite directions.

(6) *One-way.* A one-way road or street is one on which the movement of traffic is confined to one direction.

(7) *Two-way.* A two-way road or street is one on which traffic may move in opposing directions simultaneously. It may be either divided or undivided.

c. Installation highway designations. Installation highways will be divided into four general classifications (primary, secondary, tertiary, and patrol roads) in regard to their relative importance, and will be further classified for design and planning purposes into classes A through F in accordance with topography, land use, speed, volume, and composition of traffic as shown in tables 1-1 and 1-2.

(1) *Primary.* Primary highways, designated by the letter "P," include all installation roads and streets which serve as the main distributing arteries for all traffic originating outside and within an installation and which provides access to, through, and between the various functional areas.

(2) *Secondary.* Secondary highways, designated by the letter "S," include all installation roads and streets which supplement the primary highway system by providing access to, between, and within the various functional areas.

(3) *Tertiary.* Tertiary highways, desig-

nated by the letter "T," include all installation roads and streets which provide access from other roads and streets to individual units of facilities of a functional area.

(4) *Patrol roads.* Patrol roads, designated by the letters "PR," include all installation roads which are planned and designed for use in surveillance or in patrolling areas for security purposes. They will generally be designed for low volumes of light traffic.

(5) *Special considerations.* The above highways and roads may be required to accommodate overweight and oversize vehicles such as the Minuteman Transporter-Erector. Alignment, grades, and clearances will be adjusted, as required, to permit this traffic.

d. Types of open storage areas. Open storage areas are divided into two types according to anticipated use, as follows:

(1) *Vehicular.* A vehicular open storage area is an uncovered area planned and designed for the servicing, parking, or storing of passenger cars, trucks, tanks, or other wheeled vehicles at military installations. Various kinds of vehicular open storage areas are required by different services, as follows:

(a) Nonorganizational parking areas. Designated areas planned and designed for mass parking of privately owned visitors' vehicles, civilian employees, and attached personnel at community centers, administration buildings, hospitals, industrial buildings, barracks, quarters, housing areas, and other areas of public assembly.

(b) Organizational motor parks and motor pools. Designated areas designed and planned to provide control, security, and work space for maintenance and storage of organizational and administrative vehicles.

(c) Refueling vehicle area (Air Force). An area planned and designed for continuous operation of loaded refueling units.

(d) Post, base, and installation engineer areas. Designated areas planned and designed to provide adequate space for reception, classification, repair, and storage of vehicles and materials required for the maintenance and upkeep of buildings, grounds, and utility systems within a military installation.

(2) *Materiel.* A materiel open storage area is an uncovered area planned and designed for the storage of nonvehicular materiel and equipment at military installations.

e. Highway cross-section terms.

(1) *Roadway.* The portion of a highway, including shoulders, for vehicular use.

(2) *Roadbed.* The graded portion of a highway usually considered as the area between the intersections of top and side slopes upon which the base course, surface course, shoulders, and median are constructed.

(3) *Median.* A directional separator located between two roadways carrying traffic in opposite directions.

(4) *Shoulder.* That portion of the roadway contiguous with the pavement for accommodation of stopped vehicles.

(5) *Curb.* A vertical or sloping member along the edge of a pavement or shoulder forming part of a gutter, strengthening or protecting the edge, and clearly defining the edge to vehicle operators.

(6) *Traffic lane.* That portion of the roadway for the movement of a single line of vehicles.

(7) *Parking lane.* An auxiliary lane primarily for the parking of vehicles.

f. Vehicle types.

(1) Passenger car, truck, light-delivery truck, bus, and truck combinations are as defined by AASHTO.

(2) *Half-track.* These self-propelled tactical vehicles designed for the transportation of personnel and materiel off highways are mounted on a combination of wheels and tracks. These are vehicles such as the M2A1, M16, M3, etc.

(3) *Full-track.* These self-propelled tactical vehicles designed for the transportation of personnel and materiel off highways are mounted on full tracks. These are vehicles such as tanks (M60, M1), carriers (M113), gun and howitzer carriages, etc.

(4) Special vehicles are to be described by using service.

g. Traffic terms.

(1) *Traffic composition.* The symbol "T," with percentage limitations, represents the proportion of the total traffic that is composed of buses, trucks, tanks, etc. The remainder of traffic is composed of light-delivery trucks and passenger cars.

(2) *Traffic volume.*

(a) Average daily traffic (ADT). The average 24-hour volume is the total volume during a stated period divided by the number of days in that period. Unless otherwise stated, the period is a year.

(b) Design hourly-volume (DHV). This is a volume determined for use in design representing traffic expected to use a facility during an hour. The daily peak hour (or the average daily peak hour over a period of days) should be used as the DHV. The DHV is one of the most important parameters for design, as it is the

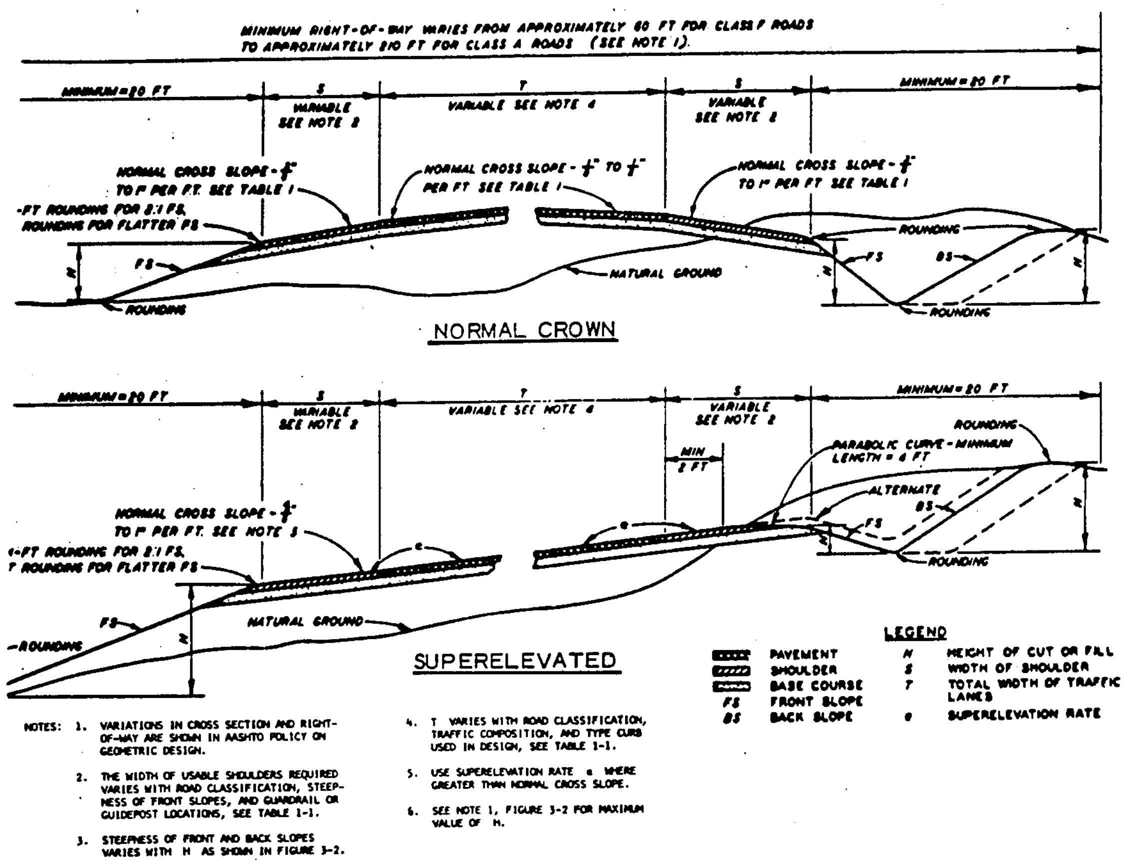

Figure 3–6. Typical road-type cross sections.

inside 2 feet of the shoulder should be held on the superelevated slope.

(2) *Streets.* Typical street-type cross sections with and without parking are shown in figure 3–7. Geometric design for the various cross-section elements shown is presented in table 1–2.

f. Intersections.

(1) *General.* Practically all highways within military installations will intersect at grade, and normally the designer will need to consider only plain unsignalized or signalized intersections. Intersections are normally closely spaced at regular intervals along streets in built-up areas, and the capacity of these streets will in most cases be controlled by intersection capacity.

(2) *Design criteria.* Geometric design criteria for intersections are presented in AASHTO publications and the TRB Highway Capacity Manual.

(3) Military installation areas equivalent to design criteria areas. Variations in average intersection capacities on one-way and two-way streets subject to fixed time signal control are shown for general types of areas within cities in the TRB Highway Capacity Manual. The curves to use at a particular location on military installations should be selected on the basis of similarity with the type of area indicated in the TRB Highway Capacity Manual. The following tabulation indicates areas in which the intersection curves should normally be used.

Appendix G
Workshop Agenda

Road Management Workshop

AGENDA

September 15-16, 1994
Eglin Air Force Base
conducted by the
U.S. Army Engineer Waterways Experiment Station (WES)

15 September 1994, Jackson Guard Conference Room

1300-1400	Problem Identification Objectives Scope	Paul Albertson, WES
	Agenda Workshop Format	John Titre, WES
	Road Management Proposal	Rick McWhite, Jackson Guard
	Roundtable Discussion Mission Support	All
1400-1415	BREAK	
1415-1530	Construction Materials at Eglin AFB: Their Occurrence and Properties	Dr. David Patrick, University of Southern Mississippi
	Unsurfaced Road Closure/ Maintenance Criteria	Stephen Webster, WES
	Unsurfaced Road Management System (Video)	Dr. Albert Bush, WES

16 September 1994

0700-0900	Field Exercise (meet at Jackson Guard) Duke Field Pilot Project Area	All
0900-0915	BREAK	
0915-1130	Workshop to Discuss: Standards Criteria and Evaluation Procedures	All
1130	Adjourn	

Appendix H
Workshop Attendees

List of Coordinators		
Richard W. McWhite	Chief of Natural Resources Division	904-882-4164
Lou Ballard	Supervisor of Fire Management Section	904-882-4164
Carl J. Petrick	Supervisor of Fish and Wildlife Section	904-882-4164
Stephen M. Seiber	Supervisor of Forest Management Section	904-882-4164
Ken Bristol	GIS Natural Resources Branch	904-882-4164
Mike Camizzi	Forestry Technician	904-882-4164
Dr. David Patrick	University of Southern Mississippi	601-266-4530
John Titre	USAEWES Environmental Laboratory	601-634-2199
Steve Webster	USAEWES Geotechnical Laboratory, Pavements	601-634-2282
Dr. Albert Bush	USAEWES Geotechnical Laboratory, Pavements	601-634-3545
Paul E. Albertson	USAEWES Geotechnical Laboratory	601-634-3148

List of Attendees		
Name	**Organization**	**Phone No.**
Henry Caldwell	AFDTC/SEU	2-4000
Charles Ray	Vitro	2-4956
Bill Chandler	Vitro	2-2991
Cyril Hopek	96 SPS	2-5431
Joe Holloway	Vitro	2-1152
Ron Ballard	46TW/TSR	2-4422
Michael Newell	96 CEG/CEOE	2-3370
Terry D. Curry	96 CEG/CEZHH	2-3844
Larry A. King	96 CEG/CEZHH	2-5536
Donnie Miller	Vitro Plans	2-5735
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Appendix I
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Paul E. Albertson, Albert J. Bush III, Steve L. Webster, John P. Titre,
David M. Patrick, James W. Brown

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road,
Vicksburg, MS 39180-6199; University of Southern Mississippi,
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13. ABSTRACT *(Maximum 200 words)*

This report presents a decision framework for road management and planning at Eglin AFB, FL. The need for a road plan was denied in the Natural Resource Management Plan. The extent of the problem is enormous because Eglin has an extensive network consisting of approximately 1,500 miles of roads. Two interrelated problems exist: (1) costs of maintaining the roads, and (2) environmental impacts. The report focuses on the second issue. The sandy nature of the installation causes chronic maintenance as well as erosion problems. In addition, road material derived from borrow pits has economic and environmental costs. The unpaved roads and clay pits act as sources of sediment which may be transported into nearby streams. Sedimentation has potential adverse impact to wetlands and stream ecology. To address these problems, a road management workshop was held to offer solutions by reaching a consensus among the various road users. Synthesis of the workshop resulted in the following conclusions: (1) establish a road task force, (2) inventory the road system in terms of mission needs, traffic volume, maintenance conditions, and environmental concerns, (3) enter data into a geographical information system for automated decision making, (4) use weighted criteria to open or close roads, (5) adopt standards for open road construction and maintenance, (6) close roads either temporarily or permanently, and (7) annually review progress. Following these recommendations will result in reducing maintenance costs and minimizing environmental consequences of roads.

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